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UNIVERSAL EXHIBITION AT PHILADELPHIA
IN 1876.

FRANCE.

NOTICES

ON

THE MODELS, CHARTS AND DRAWINGS

RELATING TO THE WORKS
OF THE "PONTS ET CHAUSSÉES" AND THE MINES
COLLECTED BY ORDER
OF THE MINISTRY OF PUBLIC WORKS.

PARIS.
GOVERNMENT PRINTING OFFICE.

M DCCC LXXVI.

Lawrence Scientific School.

ENGINEERING DEPARTMENT.

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France. Ministère des Travaux publics

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INTRODUCTION.

In the Universal Exhibition at Paris in 1867, the United States of America occupied a conspicuous position. This fact constitutes a sufficient reason why France should respond with equal cordiality to the invitation to compete in the Universal Exhibition at Philadelphia in 1876.

The Ministry of Public Works has viewed the matter in this light, and the same measures have been adopted as at the exhibitions of Paris, London and Vienna. A commission has been appointed to make a collection of models, charts, and drawings, adapted to convey some idea of the works of the «Ponts et Chaussées» and the Mines during the last few years.

The great railway companies have been solicited to co-operate in this work, and have answered the appeal with their usual promptitude.

It must however be understood, that the Government leaves to each department the responsibility as well as the merit of its own works.

Descriptive notices have been added, giving accurate details of the models, charts, and drawings, and the visitor is thus enabled to arrive at a correct appreciation of the utility and importance of the various works exhibited. Such is the object proposed by the present volume, which is divided into three parts:

FIRST PART. — "PONTS ET CHAUSSÉES".

General documents.
1st Section. — Roads.
2nd Section. — Railways.
3rd Section. — Internal navigation.
4th Section. — Maritime works.
5th Section. — Lighthouses and beacons.
6th Section. — Water supply of towns and canals.
7th Section. — Various objects.

SECOND PART. — MINES.

Unique section. — Charts and various objects.

ADDITIONAL PART. — INSTALLATION.

Industrial co-operation in the installation of the objects exhibited by the Minister of Public Works.

And finally, in order to place these explanatory notices within the comprehension of all, it has been decided that the text of this catalogue should be reproduced in an English translation made with the greatest care.

The Ministry of Public Works has confided the execution of this task to M. David **Coales**, translator, and it constitutes a separate volume intended for American visitors whose knowledge of the French language is comparatively limited.

No space inside the Palace of Philadelphia having been placed at the disposal of the Ministry of Public Works, they have been induced to construct a special building at their own expense.

The plan of this construction, its artistic decoration, the grouping of the models, charts, and drawings, are due to M. **de Dartein**, engineer «des Ponts et Chaussées», professor of architecture at the Polytechnic School, and at the «École des Ponts et Chaussées».

M. **Lavoinne**, engineer «des Ponts et Chaussées», and M. D'HERVILLY, conducteur, have been dispatched to the United States to instal the Public Works Exhibition, and are instructed to furnish all explanations desired by foreign engineers.

PREFACE

BY THE TRANSLATOR.

In rendering an ordinary work into a foreign language, some latitude is usually conceded with regard to idiom and construction, and provided that the ideas of the author be felicitously expressed, the translator is, for the most part, privileged to use his own discretion in the choice of words. In the present work, which is, properly speaking, the scientific expression of France to America, no such liberties were permissible, and the translator has therefore deemed it an imperative duty to follow the French text with rigorous exactness.

In some instances the French words have been retained, there being no English equivalents to designate them with sufficient accuracy.

This course has been necessary in the Notices on internal navigation, and especially in those referring to the Mining and Geological sections. In doubtful cases the French word has been put in a parenthesis.

The word «dike» has been employed to indicate a sea wall constructed entirely of stone, as in the port of Marseille, Saint-Jean-de-Luz, etc.

In conclusion, it need only be said that the best authorities have been consulted for a faithful rendering of the technical words.

The translator avails himself of this opportunity to acknowledge the valuable assistance rendered by M. **Malézieux**, engineer in chief and professor, and M. **Witcomb**, professor of English, both of the « École des Ponts et Chaussées »; likewise by M. **Ellis**, civil engineer.

Thanks are also due to M. **Emmery**, inspector general « des Ponts et Chaussées » and Inspector of the School, for the kindness with which he has afforded every facility for the execution of this work.

David COALES.

Translator.

FIRST PART.

"PONTS ET CHAUSSÉES."

I

GENERAL DOCUMENTS

ON

THE LINES OF COMMUNICATION IN FRANCE.

A map on a scale of $\frac{1}{320000}$ (1 metre for 320 kilometres).
A volume of text in-8°.

The lines of communication in France are divided into *terrestrial, fluvial* and *maritime.*

The terrestrial lines comprise *roads* and *railways.*

The roads are subdivided into *national* and *departmental.*

The fluvial communications embrace *rivers* and *canals.*

These different modes are shown on the map in the following manner:

National roads are represented by *a dark brown line;*

Departmental roads by *a line of the same colour* but *narrower;*

Railways are indicated by *a white line;*

Navigable rivers and canals by *a blue line.*

A conventional representation of the mountains shows the summits of the watershed and the large rivers occupying the intermediate valleys.

The principal lines of maritime navigation are figured by *gold lines.*

Various *depths of the sea from 100, 200,* and *500* to *1,000 metres,* are shown by *red lines.*

White circles mark the luminous ranges of the different lighthouses on the coast.

The map includes also the principal towns, which are distinguished as follows:

Chief towns of departments are represented by *gilt hollow-topped buttons;*

Chief towns of «arrondissements» by *black dots;*

Seaports are shown by *flat gilt buttons* of two sizes; the larger buttons indicating particularly the *great ports.*

The text, relating to the lines of communication, comprises roads, bridges, railways, rivers, canals, seaports, lighthouses and beacons.

Each of these divisions forms the subject of a special chapter, in which are condensed, the principal historical, technical, administrative, and commercial facts appertaining to it, extracted from official documents.

The map has been drawn and painted by M. DE DARTEIN, Government engineer and professor at the «École des Ponts et Chaussées», with the assistance of MM. BOULARD and CIESIELSKI.

The text has been compiled by M. Félix LUCAS, Government engineer, attached to the ministry of Public Works.

FIRST SECTION.

ROADS.

II

VIADUCT OF DINAN,

ON THE RANCE.

(NATIONAL ROAD N° 176.)

Model of three arches, scale of 0^m,04 (one twenty-fifth).

This viaduct was built for the national road n° 176, and is 315^m,50 in length. It consists of only one stage with ten semicircular arches of 16 metres span, 1 metre in thickness at the key, and 6^m,75 in breadth between the heads.

The roadway is 41^m,30 above the level of the canal of Ille-et-Rance, and the top of the parapet of the highest pier is 49^m,15 above the foundation rock.

The part of the piers visible, or above ground (the foundations being about 10 metres in depth) is 27^m,60 in height, of which the basement is 7^m,80, the shaft or body, 18^m,40, and the crown 1^m,40.

The piers are vertical, and have a uniform section of 4 metres by 6^m,65; they are flanked by small buttresses 2 metres in breadth, with a projection of 0^m,50 under the cornice and $1^{m},76$ at the base, thus giving a diminution or tapering of $0^{m},034$ per metre.

The abutments are 4 metres in thickness, $6^{m},65$ in breadth, 8 to 9 metres in height, and have return walls $38^{m},50$ in length, on the left, and 81 metres on the right bank, forming a total length of $315^{m},50$, of which, the length in the clear, between the abutments, is 196 metres.

Two longitudinal galleries extend between the abutments, and communicate with each other by openings in each pier; they lessen the mass and weight of the masonry, and facilitate the inspection and repair of the tops of the arches.

The necessary drainage having been effected by pumping, the foundations of the piers were laid on the solid rock, and are 10 metres in depth. The pressure at the top is $6^{kg},50$, at the base level $9^{kg},50$, and on the rock $8^{kg},80$.

The cost, including 81,124 fr. 27 cent. for the roads to the approaches of the viaduct, was 1,047,789 fr. 42 cent., or 103 fr. 65 cent. per square metre of elevation.

The work was accomplished between 1846 and 1852, under the direction of MM. Méquin and Gayffier, chief engineers, and M. Fessard, resident engineer « des Ponts et Chaussées ».

III

BRIDGE OF ARCOLE,

ON THE SEINE, PARIS.

Model, scale of 0^{m},04 (one twenty-fifth).

This bridge comprises only a single iron bay, with a span of 80 metres and a rise of 6^{m},12. The breadth between the balustrades is 20 metres, viz 12 metres for the roadway and 4 metres for each footway. It is composed of twelve ribs, of which the intermediate ten are 1^{m},33 apart, and the two outside ones 3^{m},50.

Each of these ribs comprises three distinct parts : a lower arch, a string piece, and a rigid spandril uniting the arch and the string piece.

These arches, having a double T section, are 0^{m},38 in height at the key and 1^{m},30 at the springing. The vertical web 0^{m},01, in thickness, is joined by four angle irons to the upper and lower horizontal flanges : these are 0^{m},53 in breadth by 0^{m},044 in thickness, for the four outer arches, and 0^{m},028 for the eight intermediate arches, which are less distant from each other; and are formed of two or three plates of sheet iron, 0^{m},015 and 0^{m},014 thick, fastened together by four rows of rivets. The arches are also stiffened by a series of T irons, in the shape of a polygonal horseshoe, riveted to the web as well as to the flanges, with a space between of about 1^{m},50.

The string pieces crowning the spandrils are in simple

T iron, of which the horizontal flange is $0^m,30$ in breadth by $0^m,015$ in thickness; the vertical web is $0^m,30$ in height and $0^m,010$ in thickness. For about 21 metres on each side of the key, the web of the string pieces extends to the arch, to which it is riveted, so as to form a spandril partly in openwork. These string pieces penetrate the abutments, and are firmly embedded in the masonry.

With the exception of the central part, where they are formed by an extension of the string pieces, the spandrils are made of double T iron, arranged to present a series of V and W, the tops of the latter being all placed on a middle arch, nearly equi-distant from the string piece and the extrados of the large arches.

The ribs are strongly braced:

1. By a double series of fifty two T irons, $0^m,20$ by $0^m,10$, three metres apart, and riveted to the intrados and extrados of all the arches;

2. By a triangulation in zigzag, formed by forty eight fish-bellied connecting bars, and extending between each outside arch and the next rib;

3. By twenty four hollow tubes, crossed by iron bars $0^m,03$ in diameter, and placed perpendicular to each of the roses of the spandrils;

4. By the flooring in Barlow rails, riveted to each rib.

This work was constructed in 1854 and 1855, according to the plans, and under the superintendence of M. Oudry, engineer «des Ponts et Chaussées».

1,200 tons of iron were employed. The cost, by contract, was 1,150.000 francs, or about 700 francs the superficial metre.

IV

SWING BRIDGE AT BREST.

A model of the bridge on the scale of $0^{m},02$ (one fiftieth).
A model of the tower and a its mechanism on the scale of $0^{m},10$ (one tenth).
Perspective view of the commercial port.

General arrangement. — This bridge affords communication between the towns of Brest and Recouvrance, separated by the Penfeld, at a height of 29 metres above the zero of the scale of tides. The clear space above high-water mark is $19^{m},50$. The distance between the facings of the abutments is 174 metres. The two iron flaps, composing this length, are supported respectively by a circular pier, of which the upper diameter is $10^{m},60$. The distance between the piers, from centre to centre, is 117 metres; the clear breadth of the passage is therefore about 106 metres, when the bridge is open. This breadth is nearly the same as that of the channel which forms the naval port, so that the construction of the bridge, which is situated at the entrance, has offered no obstacle to the passage of ships of war.

Bridge flooring. — The two flaps which carry the flooring are each $7^{m},72$ in height at the piers, and $1^{m},40$ at the centre extremities. The roadway is 5 metres in breadth, and the footways $1^{m},10$. Each flap is formed of two girders, each girder being composed of an upper and lower piece, T shaped in the section, and braced by uprights and cross-ties in the form ×. In the perpendicular of each upright, the girders are bound by ties and pairs of diagonal stays. As the bridge, while turning, is subject to deflection, transversal to its length, it was indispensable to strengthen it considerably in this direction. With this view advantage was taken of the flooring. It was made of two courses of timber, overlaid so as to cross all the joints, and thus constitute an inflexible surface, while underneath, the girders are bound and strengthened by a complete network of cross-ties and pairs of diagonal stays, extending from the centre of rotation the whole length of the bridge.

The breech of each flap is in the form of a chest, and contains the counterpoise weight, necessary to preserve the equilibrium. The most difficult point in the construction of the flaps, was the arrangement of the parts above the piers, since it is here that the action of dead weight is experienced, as well as other effects due to rotation. It was necessary to protect the frame work against these strains, and being placed on a bed of friction rollers, it was effect essential to distribute the weight as equally as possible upon all the rollers. To effect this the division of the girder uprights has been regulated so as to correspond with the middle of the friction rollers, and thus form four principal points of support, which are, strengthened by means of pillars. These pillars are bound together by four strong diagonal stays, in addition to a sheet iron tower strongly fastened, and having a platform at the top and bottom. This meeting of parts forms a solid foundation, in relation to the girders and friction beds, and consequently capable of performing the functions just indicated.

Friction tables.—These are the same in principle as the railway turntables, but have a diameter of 9 metres, and being subjected to a weight of 600,000 kilogrammes, the dimensions are necessarily considerable. There are fifty rollers, with an average diameter of $0^m,50$, and a length of $0^m,60$. The tables have been turned with exceptional care, and for this purpose special machinery was constructed at Creusot, at a cost of 75,000 francs.

Machinery of rotation. — The immovable part of the turntables is furnished with cogs at its circumference, to which a pinion wheel corresponds, having its axis in the movable turntable. This pinion is turned by a cog wheel, moved by a second pinion, set in the main shaft. This last is vertical, and reaches to the flooring of the bridge, where it is fitted with a cross head for the capstan bars worked by the bridge men. The rotation finished, the capstan head is lowered under the flooring, and the bridge is immediately clear for traffic. This machinery is at the same time simple, convenient, and powerful. Simple, because the action is nearly direct; convenient, because the men can watch the effect of the machinery from the top of the bridge; powerful, because the number of men working it, can be increased in case of necessity.

Wedging machinery. — To insure the stability of the superstructure, during the traffic, a system of chocks or wedges, has been adjusted in front and rear of the flaps. In front, they are simply iron bolts, which go from the end of one flap to the end of the other, thus binding the two together. In the rear, they are levers similar to the jaws of a vice in a horizontal position. The point seized by these levers, is formed by a piece of cast iron let into the solid abutment. On the other hand, the axes of the levers hold to the framework of the breech. There are two sets of levers to each breech, and two sets of bolts at the junction of the flaps. In addition to this, to relieve the rollers of the enormous weight to which they are subjected, two jack screws have been fixed at the commencement of the incline of each flap. These screws are supported on plates bedded in the crown of the pier. Each of them is intended to raise one of the girders of the flap, and is formed of a strong screw fixed to the girder, and a female screw, of which the head forms a cog wheel. This works on a vertical pinion, with a pulley for an endless chain. The chains of the two jack screws of each flap, work in a double pulley set in a vertical shaft, which moves a jointed capstan; this latter is lowered and kept under the flooring of the bridge. The jack screws are put in action before the bridge is open for traffic.

The working. — To work the flaps, the bridge keepers begin by withdrawing the bolts in the centre; then the wedges and chocks at the abutments. The rotation is effected by means of the capstan above mentioned. In perfectly calm weather, with two men at each flap, the bridge can be opened or shut in fifteen minutes at most.

Masonry. — All the stonework has its foundation on the solid rock. The facings of the piers are in dressed freestone; those of the abutments are in dressed quarry stone with chain courses of dressed ashlar at the angles.

Erection of the iron superstructure. — This was effected by means of a foot-bridge, the flaps being parallel to the channel. The work finished the flaps were brought together at the same level. Platforms had been fixed, for the observation of the level of high tides, in adjusting their elevation.

Repairs. — A work like the bridge of Brest, containing such a number of pieces adjusted to each other, necessitated some foresight in respect of damage and wear and tear of metal. In this respect, the rollers and friction beds are in the same position as the rest of the machinery. It was necessary to isolate them, at need, from the pressure of the bridge, and arrangements were made for temporarily establishing, on the solid piers, and below the girders, hydraulic presses, capable of a pressure of 200,000 kilogrammes. The water is forced into all the presses by a single play of the pumps placed in the centre of the tower. These pumps are worked by hand like a fire engine. During the experiments made at the inaugural opening of the bridge, eight men raised the bridge some centimetres above the friction rollers in less than ten minutes, and all the friction apparatus could be taken to pieces and reset without difficulty.

Plans and construction. — MM. Cadiat and Oudry executed the first designs of the bridge, but the plan carried out is different, and M. Oudry alone is the author. All the masonry, wood and iron work was done by MM. Schneider and Company of Creusot, of whom M. Mathieu is the chief engineer. MM. Maitrot de Varennes and Aumaître, engineers in chief «des Ponts et Chaussées».

and Rousseau, resident engineer, were appointed to the superintendence of the work. The masonry was sublet to a firm in Brest, and executed by M. Letessier de Launay, contractor.

Measurement. — The weight of metal employed may be estimated as follows :

Ironwork of all descriptions.......	860,000 kg.
Fitted castings.................	340,000
Total...........	1,200,000 kg.

The cubic measurement of the wood, for the road and footways, is 150 cubic metres.

Cost. — The cost of the bridge over the Penfeld was 2,118,835 fr. 10 cent. This sum is distributed as follows :

Masonry of piers, abutments and approaches....................	698,743f,10
Iron flaps.....................	1,180,290 ,00
Centres and mounting the flaps....	119,710 ,00
Accessory work of flaps...........	54,426 ,90
On account for various expenses....	65,665 ,10
Total..........	2,118,835f,10

V

BRIDGE OF SAINT-SAUVEUR,

ON THE GAVE, PAU.

(NATIONAL ROAD N° 21.)

Model one twenty-fifth, scale of 0m,04.

This bridge, which serves the national road n° 21, is formed of a single semi-circular arch with a span of 42 metres.

Length between the approaches	66m,20
Breadth between the bridge heads	4 ,90
Breadth between the outer faces of the balustrades	6, 20
Thickness at the key	1 ,45
Height of roadway above low water-mark	65 ,50

The carriage way is 4m,50 in width between two footways 0m,85 in breadth, the cast iron balustrade included. These footways are corbelled out, and supported by brackets.

The arch rests upon the solid rock, which thus serves for abutments. The crowns of the arch, brackets and plinths, are in dressed stone; the main body of the vaulting, in rag-stone rubble and Vassy cement; and the spandrils in calcareous rubbles, and fat lime, mixed with a tenth of Vassy cement.

For the construction of this bridge it was necessary to erect a scaffolding in the river Gave, and to carry a platform level with the springing of the arch, in order to prevent any movement of the centres from their perpendicular.

This scaffolding was composed of six uprights, two and two, in planes parallel to the axis of the bridge; the three uprights of each row being distant 6 metres, from centre to centre; two presented in the other direction a diminution of 0^{m},05 per metre, and the distance between them at the level of the Gave, was 7^{m},75, and at the level of the springing, 4 metres.

These uprights were cross braced by twenty-eight vertical diagonal stays, twelve perpendicular, and sixteen parallel to the stream; the system was completed by twelve horizontal cap-pieces, parallel to the heads of the bridge, with eight double ties perpendicular to them; the height between the Gave and the springers was thus divided into four stages, with a height of 9^{m},50. Each of the lower uprights rested on a post of deal, filled round with a pyramid of cement, two metres in the slope. The uprights were 0^{m},35 by 0^{m},35; the diagonal stays, 0^{m},30 by 0^{m},25; the cap-pieces, 0^{m},35 by 0^{m},30; the ties, 0^{m},30 by 0^{m},25 square. This foundation scaffolding required 220 cubic metres of pine.

The horizontal platform, 12 metres in breadth, was formed of cross beams resting on longitudinal beams, on the banks and centre piling, and supported by struts. In the same manner, this platform was built up to the lower part of the centre, in two stages, one 8 metres, the other 6 metres, together 14 metres in height.

The centering comprised four ribs or frames; the two middle ones being 1^{m},80 apart, and 1^{m},475 from the head centres. Each centre was composed of six beams, 0^{m},30 by 0^{m},35 square and 11^{m},70 in length, mutually supporting each other, two and two symmetrically, directly, or by means of tie-beams. These frames were bound together by two courses of horizontal ties, 0^{m},35 by 0^{m},25 and 15^{m},80 in length, sixteen queen posts 0^{m},30 by 0^{m},20; forty courses of horizontal ties bound the four centres together. The cubic measurement of the deal was 277 metres for the four centres. The centres were removed by means of jack screws, and the settling observed, was 0^{m},005.

The works were commenced in 1860, by order of the emperor Napoléon III, and the bridge was opened for traffic on the 30th June 1861.

The total cost was 318,637 francs, of which sum 121,092 francs were expended in provisional works. The superficial metre may be calculated at 982 francs, from which must be deducted 373 francs for the provisional works.

The bridge was planned and executed by MM. Schérer and Marx, engineers in chief, and Bruniquel, resident engineer des « Ponts et Chaussées. »

SECOND SECTION.

RAILWAYS.

VI

BRIDGE OF TARASCON,

ON THE RHÔNE.

(LYON AND MARSEILLE LINE.)

Model of an abutment, an arch, and a pier, scale of 0^{m},04 (one twenty-fifth).

This work was constructed to form a connection between the principal line of the Lyon and Mediterranean Railway, and the roads on the right bank of the Rhône, and consists of seven cast iron arches of 60 metres span with 5 metres rise.

Length in the clear between the abutments		438^{m},00
Breadth between the balustrades		9 ,08
Length of the piers (including the two half-cylinders) at the ends		21 ,00
Breadth of the piers		9 ,00
Solid mass of concrete at the foundation	length	24 ,50
	breadth	12 ,70
Uniform thickness of iron arches		1 ,70

The piers, sufficiently thick to form abutments, are corbelled out 1 metre at each springing of the arches, which gives 62 metres clear between two; the pressure of the arches is received by blocks of dressed granite.

Each arch is composed of eight ribs $1^{m},25$ apart, except the outer ones, which are $1^{m},35$ from the others; and each rib is composed of a cast iron arch, fixed to spandrils, which support the continuous flooring also, the cornices, parapets, ballast and line.

An arch is formed of seventeen voussoirs $1^{m},70$ in height, with a thickness of $0^{m},05$; they are provided with three courses of flanges $0^{m},05$ thick, but the total breadth of the two outer ones is $0^{m},40$, and of the intermediate $0^{m},20$; an average thickness of $0^{m},096$ is thus obtained for the voussoirs, which mutually support each other, by carefully finished joints $0^{m},40$ in breadth, fastened by eight bolts $0^{m},05$ in diameter. The arches are connected by a double system of cross ties; the upper bracing is effected by strong cast iron frames, forming a grooved plateau $1^{m},415$ broad, $0^{m},18$ high and $0^{m},04$ in thickness, without including the flanges. They are placed on the upper flange of the arches, and, by a dove-tail mortise, hold simultaneously the two contiguous voussoirs, and rigidly maintain the position of the successive arches. The lower bracing, auxiliary to the preceding, only comprises half the number of ties, $0^{m},625$ in breadth by $0^{m},16$ in height, leaving the two contiguous voussoirs of the same arch perfectly free. The rigidity of this system prevents horizontal deflection by change of temperature.

The spandrils are formed of uprights and frames. The uprights, though grooved, are rigid, and have a surface of $1^{m},10$; they are placed perpendicular to each joint of the voussoirs; the frames, which are lighter and considerably grooved, vary in length according to the space between the successive standards. These pieces are supported, either on the upper part of the voussoirs, or on the cross-ties between the joints,

The flooring is composed of a series of plates $0^m,018$ in thickness, curved to $0^m,09$, bolted to each other and to the spandrils. A cast iron cornice and parapet complete the upper part of the structure.

The bed of the river consists of sand, above a stratum, of gravel varying in thickness, but washed away by the action of the water to a depth of 10 metres.

The piers rest on a solid mass of beton, contained in an enclosure of sheet piling, at a depth of 10 metres below low water. To drain this enclosure, it was necessary to drive a second row of piles $3^m,20$ distant from the first, and in this space were laid four courses of square blocks $0^m,70$ in height, and weighing about 6,000 kilogrammes each; these blocks prevented the shingle and gravel from falling into the excavation. A steam pile-driver was employed.

The weight of a pier is 11,000 tons; then adding 1,100 tons for castings, 600 tons for ballast, and 300 tons for the weight of two trains, a total weight is reached of 13,000 tons on the sand, or 5 kilogrammes to the square centimetre.

By means of the numerous tests to which the bridge was subjected, at the time of opening, it was ascertained that the cross bracing had the effect of lessening and regulating the difference of temperature between the arches; that the rise at the key was $0^m,00135$ per degree centigrade; that the lowering at the key was in proportion to the permanent weight, and 0^m,00475 per hundred tons; and that the addition of rolling weight, resulting from the simultaneous passage of two trains, caused a lowering of the keys from 0^m,002 to 0^m,011.

The cost of the work was 6,500,000 francs, or about 1,450 francs the superficial metre. A period of five years elapsed between the commencement and completion of this bridge, but this includes an interruption of eighteen months, and it was opened for traffic in 1859.

This work was constructed by MM. TALABOT, engineer in chief, and DESPLACES, resident engineer «des Ponts et Chaussées». (See *Annales des Ponts et Chaussées,* 1854.)

VII

IRON VIADUCT OF BUSSEAU-D'AHUN,

ON THE CREUSE.

(MONTLUÇON AND LIMOGES LINE.)

Model of a pier and fraction of the flooring scale of 0^{m},04
(one twenty-fifth).
General drawing, scale of 0^{m},005.

This viaduct, constructed for the Montluçon and Limoges railway, crosses the river at 56^{m},50 above low water-mark, and consists of six bays, four of which have a span of 50 metres, one 45^{m},25, and one 41^{m},25. They are supported by two abutments in masonry and five piers in iron framework, resting on basements in masonry.

Total length, including approaches				338^{m},70
Length of flooring				286 ,50
Height of rails above basement				38 ,90
Height of girders				4 ,43
Breadth between parapets				8 ,00
Piers in river.	Iron work	Total height		33 ,85
		Dimensions at top	2^{m},00 by	6 ,00
		Dimensions at base	3 ,40 by	10 ,20
	Masonry	Maximum height above foundations		17 ,90
		Dimensions at top	2^{m},00 by	6 ,00
		Dimensions at base	12 ,94 by	15 ,29
		Starlings 6^{m},55 in height.	2 ,89 by	6 ,53

A pyramidal arrangement has been adopted in these piers; in other words, the standards and basement faces converge towards a point in the axis of each pier, at a height of 38^{m},80 above the rails. From this circumstance, in addition to the dimensions of the upper plateau, which is a rectangle of 2 metres by 6, it follows that the diminution 0^{m},067, in the direction of the stream, is triple the diminution 0^{m},022, in the direction of the railway.

The iron work of each pier consists of eight cast iron pillars in two pier frames. The total height comprises, eight annular foot plates 1^{m},20, joined by a cast iron balustrade of the same height, which also binds the stonework of the basement; seven stages, each 4^{m},50 in height, consisting of standards or hollow pillars bound together by diagonal stays, a crown and hinged capital 1^{m},15 in height and supporting the flooring.

The pillars have a uniform exterior diameter of 0^{m},35 for all the stages; the thickness of the casting is 0^{m},055 for the first stage; 0^{m},050 for the second and third; 0^{m},045 for the fourth and fifth, and 0^{m},040 for the two last. The successive lengths are joined by four bolts 0^{m},045 in diameter. The pillars are 2 metres apart at the summit, and 3^{m},40 at the base; the plane of each stage consists of three squares in juxtaposition, and this arrangement is observed throughout in the height of the pier. The squares are 2 metres by 6 at the crown, and 3^{m},40 by 10^{m},20 at the basement. The eight columns of each stage are braced by pairs of diagonal stays, in the form of Saint-Andrew's cross, six of which connect the pillars of one frame, and four unite the two frames to each other. There are also ten horizontal braces, six of which are parallel to the axis of the pier in plan, and four perpendicular to it; these are all placed at the points of junctions of the successive stages. The cross bars are double and are formed of U iron $0^{m},10$ in breadth by $0^{m},011$ in thickness, with branches $0^{m},04$ and $0^{m},045$ projection. The braces are $0^{m},25$ in depth and $0^{m},125$ in breadth; they are made of two T irons, arranged crosswise, each having $0^{m},125$ base, with the same height, and $0^{m},012$ thickness. The horizontal cross bars, forming the diagonals of the three squares constituted at each stage by the ten cross braces, are in T iron, with a base $0^{m},07$ by $0^{m},012$ in thickness and a flange $0^{m},06$ by $0^{m},011$.

To resist the effects of the wind and the traction strain, the standards have been strongly secured; for this purpose vertical rods, $0^{m},06$ to $0^{m},10$ in diameter, have been let into the masonry of the pier $3^{m},70$ to $5^{m},50$ and keyed below to plates; they pass through the foot plates, to which they are secured at the upper level of the balustrade by screw bolts inside the standards. A sufficient initial tension was thus given to these bars, to prevent the traction strain from imparting a dangerous oscillation to the piers.

Assuming the most unfavourable circumstances of excess weight, expansion, or wind, the maximum strain upon the outer standards would be $4^{kg},75$ of compression and $0^{kg},92$ extension; while the action on the cross bars would be $6^{kg},3$ of extension and on the braces $2^{kg},3$.

The annular foot plates exercise a maximum pressure on the crowns of the masonry piers of 48 kilogrammes per square centimetre. They rest on three courses of Volvic lava, of which the stones are $0^{m},65$ thick and more than

$2^{m},30$ in surface, so that the pressure transmitted to the masonry is reduced to 8 kilogrammes per square centimetre.

The metallic flooring consists of four girders, 2 metres apart from centre to centre, and connected so as to form a single piece extending from one abutment to the other; they are $4^{m},43$ in height.

Each girder is composed of two flanges joined in lattice. The flanges are $0^{m},50$ in breadth by $0^{m},042$ in thickness, and are formed of three plates of iron, and two angle irons $0^{m},20$ by $0^{m},10$, and $0^{m},016$ in thickness, holding the lattice. This lattice is made of flat iron bars to resist tension, and with double T iron to resist compression; they are $0^{m},15$ in breadth and $1^{m},40$ apart. The girders are additionally strengthened at each standard by strong vertical stiffeners of double T iron, and two or three thicknesses of iron plate $0^{m},50$ in breadth, $0^{m},20$ in table and $4^{m},43$ in height.

The vertical bracing is effected by a series of diagonal stays 4 metres apart; they are in U iron $0^{m},10$ by $0^{m},011$ thick, $0^{m},04$ projection, and crossed at half their height, by a flat iron bar $0^{m},08$ by $0^{m},02$. Horizontally, the girders are fastened by a series of diagonal stays, above and below, extending between the two central beams, binding the girders two and two, and constituting the diagonals of a succession of squares with sides of 2 metres. The principal abutment girders are only fastened to the next girders, by a series of single diagonals or half crosses; the U irons of all these crosses are $0^{m},10$ by $0^{m},011$ by $0^{m},04$ projection. In the perpendicular of each vertical cross is a brace, binding the three girders, and made of T iron $0^{m},125$ by $0^{m},15$ and $0^{m},013$.

The joists are 2 metres apart and placed at the top of the trellis; they are in T iron with a table of $0^{m},15$ by $0^{m},30$ in height by $0^{m},01$ in thickness, and angle irons $0^{m},07$ by $0^{m},012$. Between two of them two strong angle irons have been introduced, $0^{m},125$ in depth and $0^{m},0125$ thick, which are riveted to the lower beams and trussing of the longitudinal rail-sleepers. This arrangement reduces to $0^{m},67$ the distance between the points of support of the flooring, which is composed of runners $0^{m},15$ in thickness.

Each girder has only one bearing upon the heads of the piers; and this plan has been adopted to avoid the unequal distribution of weight between the standards of the two pier frames, during the passage of the trains. In fact, a single standard would have been subjected, at frequent intervals, to a compression of 183 tons, and immediately afterwards, to a tension of 50 tons. Between each girder and the crown of the pier, a hinged capital has been interposed, forming a single point of support which allows the flooring to incline freely, with an oscillation of $0^{m},013$ in each direction in the perpendicular of each frame, without straining its supports. The four capitals of a single pier are $0^{m},62$ in height, and are connected by two round iron bars $0^{m},07$ in diameter.

To prevent the additional strain on the standards, which would have resulted from the action of the flooring upon the piers, during a movement of expansion, friction rollers have been placed on the small piers and on the abutments.

The raising of the iron piers was effected by using the framing launched from the side, as a service bridge. This plan allowed all the parts of the pier to be lowered by means of a crane, and placed in position without a scaffolding.

The total cost amounted to 1,514,989 francs, or 4,473 francs per metre run and 126 fr. per square metre of elevation, solid parts and spaces taken together. The average cost is 2,870 francs per metre of elevation from the basement at the rate of 37 francs per square metre; 2,322 francs per metre of elevation for the iron pier, and 2,705 francs per metre run for the flooring. In the iron part of one great pier were employed 100 tons of castings, at 43 centimes per kilogramme, and 56 tons of wrought iron at 60 centimes. The maximum deflection of the bays during the tests, was $0^{m},01$ under a uniform excess weight, and $0^{m},025$ for a bay loaded with 8,000 kilogrammes per metre run, between two bays, the one vacant, the other weighted with 1,000 kilogrammes per metre run.

The viaduct was constructed from 1863 to 1865 under the direction of MM. THIRION, engineer in chief «des Ponts et Chaussées» and director of the central lines of the Orleans Railway Company, NORDLING, engineer in chief, and GEOFFROY, resident engineer of the same line. The iron work was executed by MM. CAIL and Company.

VIII

IRON VIADUCT OF LA CÈRE.

(FIGEAC AND AURILLAC LINE.)

Model of a pier and a fraction of the flooring, scale 0^{m},04 (one twenty-fifth).
General drawing, scale 0^{m},005.

This viaduct was constructed on the Cère, for the passage of the railway from Figeac to Aurillac, and crosses the river at 55^{m},30 above low water-mark. It consists of five iron bays, of which one is 41^{m},25, three 50 metres, and one 45^{m},25, supported by two abutments in masonry, and four iron piers, resting on stone basements.

Total length, including approaches					308^{m},50
Length of flooring					236 ,50
Height of rails above basement					39 ,00
Height of girders					4 ,42
Breadth between parapets					4 ,50
Piers.	Iron part.	Total height			33 ,87
		Dimensions at top		2^{m},50 by	5 ,00
		Dimensions at base		4 ,60 by	9 ,30
	Masonry.	Height above foundations			17 ,20
		Dimensions of ellipses.	Top	6^{m},50 by	12 ,80
			Base	8 ,08 by	16 ,16

This viaduct was planned by the same engineers that directed the construction of that of Busseau-d'Ahun, and having been executed in the same foundries, etc., it presents a strong resemblance to it in the details. An important difference between the two consists in the fact of la

Cère viaduct being constructed for a single line of railway, supported by two girders $3^{m},50$ apart.

Similarly, the pyramidal form has been adhered to in the piers, which are in truncated elliptic cones or octagonal pyramids, having a common summit $31^{m},20$ above the rails.

In order to reconcile this form with the broad and strong base required, as well as to make the flooring, of which the points of support form a rectangle of $3^{m},50$ by 42 metres, rest on the polygon formed by the tops of the standards, a polygonal arrangement has been adopted in plan for the piers. Their section is throughout, an octagon composed of a central square, extended by two isosceles trapeziums, of which the lesser side and height are equal to half the side of the square. The dimensions are 5 metres by $2^{m},50$ at the capital, and $9^{m},10$ by $4^{m},60$ at the base. Consequently the diminution of the intermediate standards is $0^{m},033$ in the direction of the line, and $0^{m},067$ in the direction of the stream; the diminution of the outer standards is half this amount.

The piers are composed of eight standards, or hollow cast iron pillars, resting on foot plates, joined by a balustrade, and surmounted by a capping and hinged capital. The stages, seven in number, are $4^{m},50$ in height; the external diameter of the outer pillars is $0^{m},30$, the thickness of the iron is $0^{m},045$ for the first stage, $0^{m},040$ for the second, $0^{m},035$ for the third and $0^{m},030$ for the four upper stages; the thickness for the intermediate standards is $0^{m},030$ throughout.

The standards are connected and braced by diagonal stays and cross-ties; there are however, two cross bars to a stage, on the surfaces parallel to the line, and they are reduced to two half-diagonals on the four chamfered corners.

The U irons of the cross-pieces are of the same dimensions as at Busseau-d'Ahun, $0^{m},100$ — $0^{m},040$ — $0^{m},011$; the same with the cross-braces, of which the T irons are each $0^{m},125$ — $0^{m},125$ — $0^{m},012$; also the horizontal crosses in T iron, are $0^{m},070$, — $0^{m},60$, — $0^{m},012$.

Iron bars $0^{m},10$ in diameter, pass through the foot plates, and are let into the stonework to a depth of $6^{m},50$.

Under the most unfavourable conditions, the maximum strain of the standards would be $4^{kg},91$ from compression, and $1^{kg},27$ from extension; the strain of the cross-pieces $5^{kg},4$, and that of the cross-braces $2^{kg},1$.

The crown of the basements is composed of two and three courses of granitic stone, capable of supporting a maximum pressure of 27 kilogrammes per square centimetre; the rubble is not required to support more than 8 kilogrammes.

The plan adopted for the flooring is identically the same as that of the viaduct of Busseau-d'Ahun. The only difference to notice is in the number of girders, reduced to two for a single line, and the distance between them, $3^{m},50$ instead of 2 metres; also as the rails are not perpendicular to the girders, the depth of the joists has been increased $0^{m},10$.

The hinged capitals have also been employed in the viaduct of the Cère, as well as the friction and expansion rollers on the small piers and abutments, in the same manner as at Busseau-d'Ahun.

Finally, the raising of the piers and launching of the flooring were effected by similar means.

The total cost reached 858,489 francs, or 2,783 francs per metre run, and 85 francs per square metre of elevation; the average cost is 1,820 francs per metre of height from the basement, at the rate of 30 francs per square metre, — 2,010 francs per metre of height for the iron pier, — 1,502 francs per metre run of the flooring. For the metallic part of one pier, 73 tons of cast iron at $0^f,45$ per kilogramme, and 52 tons of wrought iron at $0^f,62$ were employed.

During the tests, under a uniform weight of 4,000 kilogrammes per metre run of the flooring, the great piers showed a compression of $0^m,006$, and the middle of the bays a lowering of $0^m,018$, which reduces the deflection to $0^m,012$ for 50 metres span.

The construction of the viaduct was accomplished from 1863 to 1865.

The works, planned by M. Nordling, engineer in chief of the Orleans Railway Company, were executed under the direction of M. Deglin, engineer in chief «des Ponts et Chaussées» and of the Company, and of M. Bertoux, engineer of the Company. The iron work was executed by the firm of Cail and Company.

IX

BRIDGE OF CHALONNES,

ON THE LOIRE.

(ANGERS AND NIORT LINE.)

Model of two arches, three piers and a centre, scale 0^{m},04 (one twenty-fifth).

The bridge of Chalonnes was constructed for the railway from Angers to Niort, and is composed of seventeen elliptic arches of 30 metres span.

The abutments comprise in addition, two small bays of 4 metres for the towing-paths.

Length bethween extremities of parapets.........	601^{m},50
Length in the clear between abutments..........	566 ,00
Breadth between bridge heads..................	8 ,00
Thickness at key...........................	1 ,35
Thickness of piers at springings of arches........	3 ,50
Thickness of piers at base of socle...............	4 ,10
Thickness of abutments......................	17 ,75
Height under key from below low water-mark.....	9 ,37

The spandrils are lightened by two longitudinal arches 2^{m},20 in diameter.

The socles and buttresses form three successive offsets of 0^{m},15, 0^{m},08 and 0^{m},07, capped by dressed ashlar; the rest of the work, to the plinths, is in rubble. The parapet, generally pierced, is corbelled out.

The bottom of the river consists of sand and shingle, resting on schist and coal grit.

In the first half of the river bed, the rock is horizontal at depths of $3^{m},75$ to $4^{m},65$ below low water mark; and the foundations of the right abutment and the eight first piers were laid by means of coffer-dams.

In the second half of the river bed, the rock dipped successively to $8^{m},75$ at the sixteenth pier, and there the foundation was laid on beton run into an enclosure of jointed piling.

The centerings comprised six ribs with five points of support, two of which were on the socles, and three on the double rows of piles; the settling of the arches, after striking the centres, was $0^{m},05$.

The work was commenced in July 1863, and finished at the end of 1865.

The cost amounted to 2,149,000 francs, or 447 francs per square metre.

It was planned and executed by MM. **Morandière**, engineer in chief «des Ponts et Chaussées» and director of the new works of the Orleans Railway Company; **Croizette-Desnoyers**, engineer in chief; **Moreau** and **Dubreil**, engineers «des Ponts et Chaussées», attached to the same Company.

X

THE PORT-LAUNAY VIADUCT,

ON THE AULNE.

(CHÂTEAULIN AND BREST LINE.)

Model representing three arches and four piers, scale 0^{m},04 (one twenty-fifth).

This viaduct was constructed for the railway from Châteaulin to Brest, and comprises 12 arches of 22 metres span.

Total length between parapets	337^{m},00
Breadth between heads	8 ,50
Height above valley	48 ,40
Height above ordinary tides	52 ,50
Height above foundation rock	54 ,70
Thickness of piers at springings	4, 80
Thickness of piers above socles	6 ,13
Thickness of arches at key	1 ,05

The viaduct is situated 500 metres above the last lock of the Aulne, and on a navigable water-course, and this fact precluded the construction of two superposed stages, and also the support of the piers by smaller arches.

Above the foundation, the depth of which varies, each pier is composed of a socle 10 metres in height, and a shaft 4^{m},80 in thickness at the springings and 23^{m},30 in height; the faces have a diminution of 0^{m},02 in the direction of the length of the viaduct, and 0^{m},03 in that of its breadth. The base of the shaft has a set-off above the socle, 0^{m},20 in breadth and 0^{m},10 in length. The basements, which are rectangular for the valley piers, are rounded off in the form of starlings for the river piers.

Above the basements, the buttresses support the piers and rise to the crown of the work; their breadth throughout is equal to half the thickness of the piers, and they have consequently a diminution of 0^{m},01. In the direction perpendicular to the heads, their diminution is 0^{m},07, they also form two set-offs of 0^{m},20 at the base of the shaft, and 0^{m},50 at its summit, where they have a capping 0^{m},80 in height and 0^{m},20 projection.

From these arrangements taken collectively, result the following dimensions for the piers and buttresses.

	PIERS.		BUTTRESSES.		VERTICAL distances between these points.
	LENGTH.	THICKNESS.	PROJECTION on head facings.	BREADTH.	
Below plinth.	8^{m},48	"	0^{m},20	2^{m},14	12^{m},80
At springings	9 ,24	4^{m},80	0 ,71	2 ,40	
At springings (summit of shaft).	9 ,24	4 ,80	1 ,21	"	23 ,30
At base of shaft.	10 ,64	5 ,73	2 ,15	2 ,87	
At base of shaft (top of socle).	10 ,84	6 ,13	2 ,25	3 ,07	10 ,00
At base of socle.	11 ,44	6 ,53	2 ,65	3 ,27	

The abutments are about 20 metres in length by 20 metres in height; and recesses 11^{m},30 by 5^{m},20 have been formed in them, and covered by arches.

The solid masonry is all in rough stone, the facings visible are in rustic work, and several iron armatures bind the upper courses of the voussoirs and spandrils. Three small relieving arches of $1^{m},20$ span, built on the haunches of the great arches, are supported by the spandril walls and two longitudinal walls $0^{m},80$ in thickness at the top, where they are covered with ordinary stonework to preserve regularity of surface, and two cappings, one $0^{m},05$ in mortar, the other $0^{m},015$ in bituminous cement. Lastly, a layer of gravelly sand $0^{m},60$ in minimum thickness, is interposed between the ballast and masonry; and these dispositions impart a solidarity to the different parts of the work, and render the vibrations scarcely appreciable.

The viaduct is crowned by a plinth $0^{m},45$ in height, resting on small corbels, and surmounted by a pierced parapet projecting $0^{m},15$ from the head facings. In the perpendicular of the buttresses recesses are formed $0^{m},50$ in depth.

The foundations of all the piers have been laid on a compact schistous rock, with strong inclination of strata, and covered with a layer of mud and detritus. The foundations of three piers had to be laid in the bed of the river. For pier n° 3, a simple coffer dam at half tide was sufficient; but for n^{os} 4 and 5, it was necessary to go to a depth of $5^{m},40$ below the level of the upper water-course, and $7^{m},40$ below the highest tides, in consequence of which, recourse was had to a bottomless caisson, $22^{m},75$ by $10^{m},60$ and $6^{m},90$ in height. Fixing the caisson, the weight of which was 75 tons, was greatly facilitated by the local circumstances which allowed the water to be lowered by opening the navigable passage of the Aulne, and afterwards to be raised by the action of the tide.

A service bridge composed of two lattice girders 24^{m},80 in length and 1^{m},17 in height, connected the tops of the piers, and served to supply the materials coming from both banks. These were raised as required by the aid of four screw jacks.

The pressures at the different heights are: 5^{kg},99, at the springing of the arches; 8^{kg},76, at the base of the shafts of the piers; 9^{kg},20, at the base of the socles, and 7^{kg},34, on the foundation soil.

The proportion of space to solid is 2,13.

The total measurement of the stonework is 49,490 cubic metres, of which 7,455 are in the foundations, and 42,035 above them; the cube per superficial metre is 3^{cm},46 foundations included, and the average price per cubic metre for all the masonry, is 44 francs.

The cost amounted to 2,165,000 francs, of which sum 336,000 francs were for foundations; consequently the price per superficial metre of elevation, is 151 francs, including foundations.

The works were commenced in March 1864, and, with the exception of the parapets, were finished at the close of 1866.

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The viaduct of Port-Launay was planned and superintended in its construction, by MM. MORANDIÈRE, engineer in chief «des Ponts et Chaussées» and director of the new works of the Orleans Railway Company; CROIZETTE-DESNOYERS, engineer in chief, and ARNOUX (Auguste), resident engineer «des Ponts et Chaussées», attached to the same Company. (See *Annales des Ponts et Chaussées,* 1870, 2^{e} sem.)

XI

VIADUCT OF THE POINT-DU-JOUR,

AT PARIS-AUTEUIL.

(CIRCULAR RAILWAY.)

THREE MODELS :

1. **Model of the viaduct entire. Scale of $0^{m},01$ (1 centimetre to a metre).**
2. **Model of an abutment arch. Scale of $0^{m},04$ (one twenty-fifth).**
3. **Model of two arches of the viaduct. Scale of $0^{m},04$ (one twenty-fifth).**

The crossing of the Seine, below Paris at the Point-du-Jour, between Auteuil and Grenelle, has necessitated, for the Circular Railway (1), the construction of a series of important works.

Their total length may be divided as follows :

Viaduct of Auteuil, from the station of that name to the Versailles road......................	$1,073^{m},10$
Viaduct of the Point-du-Jour, from the Versailles road to the quay of the Seine (right bank)...........................	154 ,75
Bridge viaduct over the Seine.........	242 ,95
Viaduct of Javel, on the quay of the Seine (left bank) at the commencement of the embankment........................	119 ,65
Total...............	$1,590^{m},45$

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(1) This line may, with equal justice, be entitled the Suburban Railway, since while encircling Paris, it connects the principal suburbs. (*Translator.*)

The first and second models refer to the bridge viaduct, and the third to a portion of the viaduct of Auteuil.

BRIDGE VIADUCT OF THE POINT-DU-JOUR.

This work consists, in elevation, of two perfectly distinct parts: a bridge or lower stage, intended for foot-passengers and carriages following the military road; and a viaduct or upper stage, occupying the central part of the bridge, and pertaining to the Circular Railway. Its height above the solid concrete of the foundation, is 13^{m},41, for the parapets of the bridge, and 22^{m},53 for those of the viaduct.

1. *Bridge or lower stage.* — This is composed of five elliptical arches of 30^{m},24 span and 9 metres of rise, resting on four piers and two abutments, to which are adjoined two half-piers.

Length in the clear between abutments........	174^{m},85
Width between heads......................	31 ,00
Height under keystone above low water mark....	9 ,50
Thickness at key (lateral ways)..............	1 ,00
Thickness at key (under central viaduct)........	1 ,60
Thickness of piers at springings..............	4 ,72
Thickness of piers at base on concrete.........	5 ,72
Thickness of abutments....................	5 ,20
Thickness of abutments (central part)..........	10 ,86

The width of 31 metres between the heads comprises; two parapets of 0^{m},50, two footways of 2^{m},25, two roadways in compressed asphalte 7^{m},25, and a central footway of 11 metres, corresponding to the railway viaduct.

The spandrils are lightened at the perpendicular of each pier, by three arches or vaults parallel to the stream, built in rough millstone grit and cement, $4^{m},60$ in span and $0^{m},55$ in thickness at the key. In the central part, these arches, when only supporting the footway, are in perforated bricks, and are reduced to a thickness of $0^{m},22$. The abutments of these arches are themselves pierced by eight series of bays parallel to the axis of the bridge, and having $1^{m},75$ and $2^{m},25$ of span. All these arches are supported by pillars of sufficient thickness to allow a steam roller weighing 32 tons to pass over on the lateral ways. The total void or space created by these pierced arches, is equal to 1,495 cubic metres for each arch, which diminishes by 3,300 tons the weight borne by each pier, and by $1^{kg},6$ per square centimetre for the concrete. Lastly, under each footway a vaulted sub-way has been reserved, for the purpose of containing water pipes. It is covered by a brick arch $0^{m},06$ in thickness, and is $1^{m},50$ in width by $0^{m},60$ in height.

2. *Viaduct or upper stage.* — This part of the work, comprised between two arches of 20 metres span over the quays of Auteuil and Javel, consists of 31 semicircular arches of $4^{m},80$ span.

Total length	$248^{m},80$
Height above bridge	9 ,40
Width between heads (including two parapets of $0^{m},35$)	9 ,00
Thickness at key of small arches	0 ,45
Thickness of piers	1 ,03

The piers, having a diminution of $0^{m},01$ per metre in all their faces, are $1^{m},028$ at the springings and $1^{m},21$ at the socles.

The piers and abutments are pierced by two bays of

$2^{m},25$ span and $4^{m},25$ in height under the key. These openings have been made for the convenience of pedestrians on the central footway. The spandrils $4^{m},80$, are pierced by small brick vaults of 2 metres span and $0^{m},22$ in thickness.

The arches over the quays have respectively 20 metres of span and $2^{m},65$ of rise; their thickness at the key is $0^{m},85$ and at the springings $1^{m},55$.

The foundation soil consists of a bank of chalk, covered in the bed of the river and on the left bank, by a layer of gravel, but on the right bank, by layers of clay mixed with peat and mud.

The principal and rear abutment of the right bank are founded on piling. The piles are of oak 8 metres in length, $0^{m},30$ square and penetrate the chalk to a depth of at least 2 metres. The average distance between them is $1^{m},05$, and each supports about 28 tons. They are connected by a layer of concrete $1^{m},50$ to 2 metres in thickness.

The abutment and the rear abutment of the left bank are founded on the gravel, by means of a solid mass of beton laid dry in an enclosure of piles and sheet piling.

The piers are founded on beton laid on the bank of chalk, previously cleared by dredging. The beton was run into timber caissons without bottoms, put together on the spot, i. e. on the movable scaffolding constructed for their immersion. Their dimensions are 40 metres in length, 9 metres in breadth and 8 metres in depth.

The removal of the centres was effected by means of sand boxes, and the subsidence of the arches varied from $0^{m},009$ to $0^{m},012$.

The pressures are not uniform in the length of the piers, but vary from $2^{kg},5$ to 5 kilogrammes on the surface; 3 to 6 kilogrammes on the beton, and $3^{kg},8$ to $6^{kg},5$ on the masonry at the base of the piers; while in the great elliptical arches, they attain 14 kilogrammes at the springings and $15^{kg},5$ at the key. These arches are in rough millstone grit and cement mortar. During the tests by excess weight, the pressure in the viaduct did not exceed 4 kilogrammes in the arches and $6^{kg},5$ at the base of the piers.

The total cost amounted to 2,864,232 francs, 286,157 francs of which, were paid for various expenses not included in the contract. The average price per cubic metre of the viaduct, was 25 fr. 64 cent., and per cubic metre of stone work 57 fr. 20 cent. The cost of the whole of the bridge viaduct was 11,793 francs per metre run, or 380 francs per square metre in plan, and 549 francs per square metre in elevation, solid parts and spaces taken together.

VIADUC OF POINT-DU-JOUR.

This work forms part of the Circular Suburban Railway on the right bank, and is comprised between the Versailles road, where the Auteuil viaduct terminates, and the bridge viaduct on the Seine. It consists of 26 semicircular arches of $4^{m},97$ span.

Total length	$154^{m},75$
Height above boulevard from $7^{m},22$ to	9 ,38
Thickness of piers at springings	1 ,02
Thickness of piers at socles	1 ,20
Thickness of arches at key	0 ,60
Breadth between heads	15 ,00

The establishment of a passenger station has necessitated this considerable breadth ($14^{m},20$ between the parapets).

The piers have four pierced arches of 2 metres span and $4^{m},25$ in height under the key, separated by pillars of which the central one is $1^{m},75$ in thickness, the two outer pillars $1^{m},50$, and the two intermediate ones $1^{m},125$; these arches constitute a covered footway under the viaduct.

Twelve of the pillars rest immediately on a bank of gravel; but the succeeding arches had to be built on a soil $7^{m},70$ in thickness, composed of recent alluvial deposits, with alternate layers of clay, mud and peat, the whole resting upon a layer of coarse gravel, $2^{m},90$ above low water mark. The piers consequently requiring a height of nearly 20 metres to the arches, it was considered necessary to support them by low relieving arches; and with this view, the foundations of the odd piers were dispensed with, viz one pier out of two, and were replaced by ogival arches, resting on the solid foundations of the piers of even rank. These ogival arches, of which the summits support the weight of one pier and the two adjacent demi arches, are not apparent, for they are constructed in the height of the embankment formed between the natural soil and the level of the boulevard. By means of pumping, the foundations were laid dry, notwithstanding their depth.

The socles and angles of the piers, the cornices, parapets and voussoirs of the head, are in dressed stone, the rest of the viaduct is in ashlar or rubble.

The pressure is $4^{kg},80$ per square centimetre on the foundation soil, $5^{kg},30$ on the concrete, and increases to 10 kilogrammes in the ogival arches, two of which support one pier.

The cost amounted to 541,737 francs, of which 42,413 francs were for works not included in the contract.

The average price per cubic metre of masonry is 38 fr. 32 cent., 3,501 francs per metre run of the viaduct, 418 francs per metre of elevation above the actual soil, and 142 francs above the foundation.

This work was constructed in 1864 and 1865, by MM. **Bassompierre-Sewrin**, engineer in chief, and **de Villiers du Terrage**, resident engineer «des Ponts et Chaussées». (See *Annales des Ponts et Chaussées,* 1870, 1^er^ semestre.)

XII

IRON VIADUCT ON THE BOUBLE.

(COMMENTRY AND GANNAT LINE.)

Drawings on scales varying from 0^{m},004 to 0^{m},50.

This viaduct was constructed on the Bouble for the railway from Commentry to Gannat, and crosses the river at 66^{m},10 above low water mark. It consists of six bays of 50 metres span, supported by two abutments in masonry and five iron piers resting on stone basements.

The principal dimensions are as follows:

Total length, including approaches....	395^{m},00
Length of flooring................	300 ,00
Height of rails above basement.......	62 ,00
Height of girders.................	4 ,54
Breadth between parapets..........	4 ,50
HEIGHT OF IRON PIERS:	
Central piers....................	57 ,50
Extreme piers....................	42 ,50

The five piers are constructed entirely of iron, and the three central ones have a uniform height of 55^{m},80 between the capital supporting the bays, and the stone socle, which is 1^{m},90 above the floods of the Bouble.

The great cast iron pillars or standards, four in number only, for each pier, are 50 centimetres in exterior diameter, and their thickness varies from 30 to 45 millimetres. The interior was filled with concrete to increase their weight. They are in stages 5 metres in height, each stage being bound by a system of diagonal stays, in plane and elevation.

The piers form a pyramid converging towards a point 40 metres above the level of the rails. Thus, the pillars present in face, a diminution of 25 millimetres, and transversally, a diminution of 35 millimetres; the platform at the top is $2^{m},50$ in breadth by $3^{m},50$ in length.

At the lower part, the standards are strongly supported against the action of the wind, by struts forming arch-buttresses, and embracing the three lower stages; these buttresses are described with a radius of 24 metres, and give a projection of $6^{m},60$, so that the three great central piers have a total length of $20^{m},60$ at the base.

The maximum pressures per square millimetre, are as follows: at the summit of the pier, $1^{kg},80$; at the springing of the buttresses, $1^{kg},77$; at the base, on the buttresses alone, $2^{kg},33$; and on the buttresses and pillars together, $1^{kg},38$.

A vertical cast iron pillar in the centre of each pier, sustains the horizontal bracing, and the tie-beams which unite transversally the centres of the diagonal stays. A ladder spirally encircling this pillar, facilitates the inspection of all the parts. And finally, a lightning-rod placed in the axis of the central pier, bifurcates in two branches soldered to each girder, which terminate in two points above the parapet.

The bays, composed of two lattice girders $3^{m},50$ apart, from centre to centre, rest directly on the cast iron pillars of the piers. The height of these girders is $4^{m},54$; the vertical web is in large lattice, 4 metres in breadth, by 2 metres, thus forming a double lattice. The bars in the direction of the abutments, are in U iron, and those towards the centre of the bay, in flat bars. The lattices are additionally strengthened and stiffened by uprights, at every 2 metres, formed of two angle irons, which bind and support the beams of the bridge. On these beams rest six bars of double T iron, 18 centimetres in depth and 60 centimetres apart from centre to centre, to which the flooring formed of Λ iron is riveted. This flooring is capable of great resistance, and being without covering, it can be examined and repaired.

A foot-bridge, $0^{m},70$ in breadth, has been constructed at the lower part of the road flooring; it extends the whole length of the iron viaduct, and is accessible by stairs in the interior of the abutments.

Similarly to the viaducts of Busseau-d'Ahun and la Cère, the flooring of the viaduct of la Bouble rests on the piers through the medium of a hinged capital, and all the permanent or accidental weight is thus equally distributed between the four great standards of the piers.

The flooring was constructed on the left bank of the Bouble, on a platform 150 metres in length by 25 metres in breadth, with a downward slope of $5^{m},20$ from the level of the line; it was then pushed out 50 metres beyond the abutment, and successively beyond each pier when completed.

The stone basement for each pier had been constructed previously; as well as the first three stages of the iron part, because the work of fixing the arched buttresses demanded particular care and more time.

The cast and wrought iron work of the upper stages was conveyed to the floor of the bridge, and lowered from it to its place, as had been done at Fribourg, Busseau-d'Ahun and la Cère.

The total cost was 1,100,000 francs, or 2,785 francs per metre run, and 61 fr. 45 cent. per square metre of elevation; the average cost is 1,530 francs per metre of elevation for the metallic pier and 1,400 francs per metre of the road framing.

For the metallic part of one great pier were employed, 151 tons of cast iron, at 42 centimes the kilogramme, and 45 tons of wrought iron at 55 centimes.

During the tests, the maximum deflection of the bays was $0^{m},019$ under a uniform excess weight, and $0^{m},030$ for a bay loaded with 4,000 kilogrammes per metre run, and between two bays not weighted. The central piers showed a compression of $0^{m},005$ under the dead weight.

The viaduct was constructed from 1868 to 1870 under the superintendence of M. Didion, delegate general of the Board of directors of the Orleans Railway Company, and M. Thirion, director of the central lines, by MM. W. Nordling, engineer in chief, Delom, engineer for the metallic part, and Geoffroy, engineer for the masonry and approaches.

The ironwork was confided to the firm of Cail and Company, and to the Fives-Lille Company, represented by M. Moreaux, their chief engineer.

XIII

NEW PARIS TERMINUS.

(ORLEANS RAILWAY COMPANY.)

A set of drawings on scales of $0^{m},005$ and $0^{m},02$.

The successive developments of the lines of the Orleans Railway Company, since its origin, have imparted to the metropolitan terminus an importance and energy of movement which could scarcely have been foreseen at the period when the former building was constructed. At the expiration of twenty years, it was found necessary to demolish the old station and to erect a new one, of which the annexed drawings represent the principal arrangements.

Site. — The former station was situated between the Boulevard de l'Hôpital and the Rue de la Gare. All the ground comprised between this street and the quay d'Austerlitz, was acquired for the new station, which is bounded on one side by the quay, and on the other by the Boulevard de l'Hôpital. The superficies of the station which was formerly but $4^{h},10$, is thus augmented to 10 hectares.

The general plan of the new station does not differ materially from that of the old one; the departure platform on the left, the arrival on the right; in front, i. e. at the angle of the boulevard and the quay, are the Company's offices.

Arrival and departure buildings. — The departure building which constitutes the most important part of the terminus, presents in the centre a pavilion in the fore-part, containing a vast hall and ticket offices; to the right and left are two wings, each 60 metres in length, one of which comprises the waiting rooms, and the other, luggage and registration office. A wrought and cast iron portico $6^m,50$ in width, extends along the whole length of these buildings.

From the two extremities of the edifice square buildings advance as far as the quay; these are devoted to the various accessories, viz. refreshment-rooms, postoffice, telegraph, station master's apartments, etc.

The length of the arrival building is the same as that of the departure, but the breadth is less and the construction more simple. It contains only a waiting room and a hall for the delivery of luggage. At the extremity is a building projecting on to the court, in which are situated the porter's rooms, the octroi or city dues, the goods department, and various accessory services.

The arrival platform, 190 metres in length by 40 metres in breadth, is roofed like a hall for the third of its length, while the remainder is bordered with an awning.

Covered hall. — A breadth of $51^m,50$ separates the arrival and departure buildings, and consists of eight lines and two footways. A roof of a single span covers the whole space comprised between the two buildings, and extends 100 metres beyond, to the extremity of the goods department, in order to protect the plant housed on the intermediate ways.

By its vast dimensions and exceptional span, this roof is one of the parts of the terminus which principally attract public attention.

The total length of the hall is 280 metres, and the span as before mentioned, is 51^m,50.

The ribs, 10 metres apart, are composed of two members, with cross pieces in flat and angle irons supported and connected by cast iron tie rods and wrought iron tie-beams, after the method of triangulation known as the Polonceau system.

The extremities of the ribs are sustained by ornamental cast iron brackets.

The purlins which join the ribs are made with cross bars like the ribs.

Their lower flange is curved in such a way, that the purlin is lower in the middle than at the point of junction with the ribs.

This form is less monotonous to the view than the rectilinear; it has besides the advantage of increasing the rigidity of the purlin and of more strongly bracing the main rib, which is thus held firmly throughout its height.

The weight of the iron roof, ribs included, is 1,300,000 kilogrammes. All the dimensions of the iron-work were so calculated, that at no point, even in the tie-beams, does the strain on the metal exceed 6 kilogrammes per square millimetre.

Recapitulation. — The annexed table shows the various parts of the new terminus, with the superficial dimensions of each.

1. BUILDINGS.

Company's offices			2,953^{m}
Departure building.	Great hall	600^{m}	6,068
	Waiting rooms	1,295	
	Luggage hall	1,295	
	Covered portico	1,044	
	Reserved saloon	55	
	Ticket offices	393	
	Refreshment-room and telegraph	1,386	
Arrival building			2,635
Goods department, octroi, etc			594
	Total		12,250^{m}

2. SPACES COVERED, BUT WITHOUT BUILDINGS.

Great hall for passengers	14,714^{m}
Hall for the mails, etc	2,876
Hall for parcels	6,400
Covered part of arrival platform	3,432
Total	27,422^{m}

3. SPACES NOT COVERED.

Yard of the Company's offices	653^{m}
Yard of passenger's departure building	6,144
Yard of goods departure	10,726
Open part of passengers arrival platform	5,965
Yard of goods arrival	8,684
Total	32,172^{m}

Execution of the works. — The reconstruction of the Paris terminus was pronounced of public utility on the 12th August 1863. The expropriation of the ground was carried out immediately after the accomplishment of the necessary legal formalities, and the masonry contracted for in November 1864, was commenced in the early days of the year 1865.

The new terminus was definitively opened in July 1869, the time of building being four years and a half. This period will scarcely appear long, if the importance of the work is taken into account. Besides, it must be remembered that, the new station occupying the same site as the old one, no part of the building could be demolished before being replaced, and consequently, the new erections could only be proceeded with in successive parts and under numerous disadvantages.

The ground upon which the new station is built, presented some extremely unfavourable conditions, in respect of the foundations. It was necessary to go to a depth varying from 8 to 11 metres, in order to find a suitable bottom. The proximity of the Seine, and the permeable nature of the strata, necessitated pumping to a considerable extent. This foundation work, which involved the construction of more than 2 kilometres of wall, was accomplished without accident, but at a considerable expense.

Raising the ribs of the great roof, was one of the most delicate operations of the work. It had to be effected above the footways and the lines in actual work, without interruption to the traffic. The difficulty was happily surmounted by the Creusot firm, by means of a travelling scaffolding of the same breadth as the roof, and having at the springing of the latter, a platform upon which were placed the cranes and other machines for raising the material. This plan afforded all the necessary conveniences for collecting and setting the different parts of the roof, and left the footways and lines completely free, with the single exception of the places from which the material was hoisted.

Cost. — This may be divided into four distinct parts; the acquisition of the ground; the Company's offices; the station proper; accessory works; lines, approaches, etc.

The purchase of the ground is the most important item; and reaches the sum of........................	8,350,000 ^{f}
The property acquired is 64,870 square metres, at 128 fr. 85 cent. per superficial metre including all expenses.	
The Company's offices consist of cellars, ground floor, two stories, and attics, and their cost was.............	1,640,000
The expense per square metre is 355 fr. 70 cent.	
In this sum the foundations are reckoned at 130 fr.	
The cost of the station proper was..................	6,900,000 (1)
	16,890,000

(1) These amounts are divided as follows:

DESIGNATION OF VARIOUS PARTS OF THE BUILDING.	PRICE per SQUARE METRE.	COST.
Departure building........................	520 ^{f}	3,156,000 ^{f}
Arrival building..........................	328	1,158,000
Passenger's hall..........................	70	1,030,000
Goods department..........................	66	422,000
Hall for mails, etc.......................	44	126,000
Covered part of arrival platform and awnings...	52	178,000
Parts open, yards, footways................	"	580,000
Various works including culverts, walls and enclosure gates.........................	"	250,000
TOTAL cost....................	....	6,900,000

	16,890,000 f
The accessory works, comprising lines, tables, points, etc. rectification of streets, creation of a road between the stations of Paris and Ivry, and finally the reconstruction and enlargement of the bridge of the Boulevard de la Gare, amounted to	1,110,000
Total cost	18,000,000 f

The works of which this notice presents a condensed account, were planned and executed under the chief direction of MM. Dimon, delegate general of the Board of direction, and Solacroup, director of the Company, by MM. Sevène, engineer in chief, Louis Renaud, principal architect, to whom pertains all the architectural part of the undertaking, and Gilles, *chef de section*.

The contractors were :

For the masonry : MM. Bouyer, Cohadon, Bagnard, managers of a working-men's association;

For the ironwork : the Creusot firm, principally represented by M. Mathieu, chief engineer.

XIV

STEEL RAILS

EMPLOYED

BY THE PRINCIPAL FRENCH RAILWAY COMPANIES.

Various patterns and a portfolio of drawings.

NORTHERN RAILWAY COMPANY.

Profile adopted. — For all the lines of the Northern Company, a steel rail of the Vignoles type has been adopted. This rail weighs 30^{kg},300 per metre, and is supplied by all the French iron works indiscriminately. At the present time it is rolled in the establishments of Terre-Noire, and the Society of the Creusot iron works.

Length of rail. — The normal length is 8 metres, but to facilitate the execution of large orders, it is customary to allow reduced lengths of 7, 6, and 5 metres.

Sleepers and fish-plates. — This rail is laid with sleepers at the joints, and is supported on nine points, according to the following distances apart: 0^{m},60 next to the joints, 0^{m},90 for the first space, and 1 metre for all the others. The rails are fastened to each other by means of fish-plates, pierced with four holes 0^{m},019 in diameter, to receive the bolts. They rest directly on the sleepers, in notches cut for that purpose, and are fixed to the latter by means of two galvanized iron screws for the intermediate sleepers, and four screws for the joints. The screws bind against the rail foot, which is neither pierced nor notched in its entire length.

The reasons dictating the choice of this type of rail may be summed up as follows:

Advantages of steel. — The first advantage possessed by steel rails, over those of wrought iron, arises from the fact that they wear slowly and in a parallel direction, while the best wrought iron rails rapidly deteriorate by the traffic, and are mostly past service without having lost an appreciable weight by regular wear. The experiments made by the Northern Company upon iron rails from all the different works, have demonstrated that those of the best quality did not resist the wear and tear of a traffic exceeding 20 millions of tons; while those of ordinary quality succumb to a circulation of 14 millions. With regard to steel rails, all the trials show that the flange wears in a uniform proportion of one millimetre of thickness for a traffic of 20 millions of tons, and as they are constructed for a wear of 10 millimetres, it may be calculated that the duration of steel rails will correspond to a traffic of at least 200 millions of tons, i. e. that they will last ten times as long as the best rails in wrought iron. It follows then, that the substitution of steel for iron rails, will effect a considerable saving, while at the same time it secures to the line a greater equality of resistance, and increases to a considerable extent, the safety of working.

The second advantage of steel rails results from the fact that the material offers a resistance more equable and superior to that of wrought iron. Various experiments have been made; and comparisons instituted between the two substances, establish the fact that, when subjected to pressure, the iron rails retain permanently the set or deformation to an appreciable extent, while the tension and compression of the fibres attain to 17 and 18 kilogrammes per square millimetre. For steel rails this figure exceeds 38 kilogrammes. In direct traction tests, the metal composing the flanges of wrought iron rails of good quality, shows a resistance to fracture comprised between 28 and 36 kilogrammes per square millimetre, while for steel rails, this figure rises to between 65 and 75 kilogrammes. The wrought iron rails tested by a shock or falling weight, by the machine called *the Lyon railway,* do not resist, on the average, an active power of more than 400 kilogrammetres; while the steel rails of the type under consideration, present an opposing power of more than 900 kilogrammetres. The metal of which steel rails are formed, may then be characterised, as guaranteeing greater regularity in production, and as the powers of elastic resistance and of resistance to fracture, are at least double those of the substances composing wrought iron rails, the advantage of the substitution of steel for iron is sufficiently obvious, if the first cost of laying does not present an insurmountable objection. Now, as a matter of fact, by reducing the weight of the steel rail to 30 kilogrammes, which will still leave to it a solidity much in excess of that of the iron rail which it replaces, it is possible to modify, or nearly to annul, the difference in cost between the steel and wrought iron rail. There is therefore no longer any advantage accruing from the employment of wrought iron rails.

Detail of profile. — The conditions which have led to the adoption of the types represented by the profile and patterns attached to this description, are as follows :

To retain the height of the wrought iron rail of 37 kilogrammes, as well as the extent and inclination of range of the fish-plate and convexity of the flange, all of which have given satisfactory results.

To allow the largest possible margin for wear and tear, and with this view to increase the bulk of the flange, while reducing as much as possible the thickness of the web and the thickness and breadth of the rail-foot, without augmenting the difficulty of manufacture, or exaggerating the relation of the height of the rail to the breadth of its base.

In theory, the profile should have been such that, when the maximum of wear was reached, the work of the most deteriorated fibres of the flange and rail-foot should be the same. But this would have produced a rail too narrow and too thin at the foot, to obtain sufficient bearing on the sleepers. In the profile adopted, the equality of the strain of compression and extension is realised after a wear of 5 millimetres, but at this period, the rail is not so far weakened as to be past service, and when a second thickness of 5 millimetres is worn away, its resisting power is still superior to that of a new wrought iron rail of 37 kilogrammes.

Stability of the rail. — The new type can only be considered bolder in conception than the old rail, in respect of the stability of the base, and the proportion of this boldness is furnished by the relation of the height to the base. For the rail of 37 kilogrammes, this proportion is $\frac{125}{105}$ or 1,19, while for the steel rail of 30 kilogrammes it is 1,288. But it should be remarked that for the Vignoles iron rail, used by the Lyon Company, this proportion rises to 1,30, and for the line from Cologne to Minden to 1,356. Besides, the rail has no tendency to cant outwards, as was at first believed, under the lateral pressure it undergoes from the edges of the wheels; on the contrary it leans inwards, but the exterior screws and the inclination given to the notch in the sleeper, suffice to correct this tendency. Another result of this thrusting action, is to augment the pressure exercised by the foot of the rail against the side of the sleeper towards which the transversal movement of the wheels is directed. Now from the experience of more than two years, during which time this rail has been in use on the Northern lines, it is proved that this greater pressure does not exceed the limit that the sleepers are able to bear without detriment. It is therefore an established fact, that a diminution of the lateral dimensions of the primitive type of 37 kilogrammes, will still leave the rail in excellent condition as regards stability of foot.

Quality of the material. — These calculations and observations apply to a quality of steel characterised by a certain hardness and pertinacity of resistance, and manufactured by the French iron firms. The excellence of this quality is shown by the trials stipulated in the specifications of the Company, and which may be summed up as follows:

1st test (by pressure). — Each rail, submitted to trial, shall be placed edgewise on two points of support $1^{m},10$ apart, and must bear during the space of five minutes, in the middle of the interval between the points of support:

1. A pressure of 17,000 kilogrammes, without retaining any appreciable bend after the test;
2. A pressure of 30,000 kilogrammes, without exceeding a bend of 25 millimetres.

2nd test (by shock). — Each of the two halves of the broken rail shall be placed edgewise on two supports $1^{m},10$ apart, the said supports to be fixed on an anvil of 10,000 kilogrammes, and each of the said halves must bear, without breaking, the shock of a monkey 300 kilogrammes in weight, falling from a height of $2^{m},25$, upon the rail, in the middle of the interval between the points of support.

Under successive heights of fall of.	$1^{m},00$	$1^{m},50$	$2^{m},00$	$2^{m},25$
The bends caused by the tests must not exceed...........	2^{mm}	5^{mm}	11^{mm}	16^{mm}

Trial of new plan of laying rails (1). — At the present time a new system of laying is being tried, which consists in placing the joints of the opposite rails on different sleepers.

Although this new system has not been tried sufficiently long to be judged by experience, it is expected that the rolling will be easier than in the former system of corresponding joints. Indeed, the shocks occasioned by carriages passing over the two joints, being no longer simultaneous, their action on the movement of the carriage is modified by this single fact.

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(1) This plan, first tried in 1872, affords satisfactory results, and is adopted as the normal system of the Company.

During the last two years, in order to prevent the rails from wearing the sleepers, pieces of tarred felt have been interposed, and with good effect.

Even the violence of these shocks is lessened by the following circumstances :

1. The joint sleeper, instead of being rendered liable to start up at each extremity, is, on the contrary, retained at one of them by the pressure of the continuous rail that it supports;

2. The sleeper, receiving slighter shocks, there is less disturbance of the packing;

3. The joint happening to give way at the passage of one wheel, the carriage, supported by the other three, is kept in its position on the rails.

Length of single lines laid with steel rails. — On the 1st January 1876, this length had attained 1,310 kilometres.

Before long, the two principal arteries of the Company's system of lines, Paris to Erquelines, and Paris to Lille, will be entirely laid in steel.

EASTERN RAILWAY COMPANY.

The Eastern Railway Company, in the first place, laid some small sections of the principal lines in Bessemer steel rails, which were supplied by the principal French iron firms of (Terre-Noire, Rive-de-Gier, le Creusot, Saint-Jacques, Montluçon, Imphy).

Those rails are of the Vignoles type, and of the same profile as the wrought iron rails of 35 kilogrammes per metre run, long used on the lines. Their weight is 36 kilogrammes per metre, on account of the difference in density between the two metals.

Each rail of 6 metres rests on two joint sleepers, by the medium of bed-plates with two flanges, and on six intermediate sleepers, $0^m,90$ apart from centre to centre. The fastenings consist of galvanised screws.

At the present time there are 39,500 metres of line laid down with rails of this type.

An experiment was commenced, and is being carried on at the present time, to compare the respective duration of steel and iron rails. In March 1866, there were laid down at the Villette station, 60 rails in wrought iron and 60 rails of the Vignoles type in Bessemer steel weighing 35 kilogrammes per metre run, with the view of submitting them to comparative trials of duration and wear.

The rails were placed in identically the same conditions with regard to wear and tear, and to put this point beyond the possibility of a doubt, they were laid (on the down line), three of iron and three of steel, alternately, thus forming two groups:

The first group, comprising thirty six rails in wrought iron and thirty six in steel, was placed between the kilometres $1^k,258$ and $1^k,520$, a point where all the goods trains arrive with the brakes on, for stoppage. This part of the line is therefore subjected to great wear.

The second group, comprising twenty four rails in iron and twenty four in steel, was placed between the kilometres $1^{k},571$ and $1^{k},749$. This portion of the line is subjected to less traffic than the preceding.

In the mouth of August 1869, a third group was placed in nearly the same conditions with regard to traffic as those of the second. This group was composed of six rails of the same type, in wolfram steel fabricated by the Le Guen process.

1. *Wear.* — A first examination of the wear was made in 1872, by means of plaster casts taken of one of the three iron rails, and one of the three in Bessemer steel, alternating in each row of the two first groups.

These inspections were renewed in 1873, 1874 and 1875, casts of the same rail having been taken each time, and of the same part, viz the middle of the rail.

The verification of the wear of the rails in wolfram steel was only made in 1875.

The following tables indicate the wear ascertained, which is expressed in millimetres.

FIRST GROUP.

NUMBERS OF RAILS.	MAY 1872.	MAY 1873.	MAY 1874.	AUGUST 1875.
		WROUGHT IRON RAILS.		
3	4.5	5.3	6.1	6.4
4	4.0	5.4	5.0	5.8
8	4.5	4.9	5.4	5.8
11	6.0	6.3	Replaced in Nov. 1873.	〃
15	2.8	Replaced in June 1872.	〃	〃
16	Replaced in July 1871.	〃	〃	〃
21	3.0	3.3	3.6	3.9
22	1.5	2.0	3.0	Replaced in August 1874.
27	5.0	5.6	Replaced in Dec. 1873.	〃
28	3.0	3.7	4.3	4.6
33	4.6	4.8	5.2	Replaced in July 1874.
34	Replaced in Nov. 1868.	〃	〃	〃
AVERAGES...	3.91	4.5	4.657	5.3
		BESSEMER STEEL RAILS.		
3	3.0	3.8	4.5	4.9
4	4.0	4.3	4.6	4.9
9	3.5	3.8	4.1	4.6
10	3.5	4.0	4.5	4.9
15	3.5	4.0	4.5	4.9
16	4.0	4.5	5.0	5.3
21	3.5	3.8	4.1	4.5
22	3.5	3.9	4.3	4.6
27	4.2	4.4	4.6	4.9
28	4.0	4.5	4.9	5.2
33	2.5	2.8	3.1	3.3
34	3.2	3.6	4.0	4.2
AVERAGES...	3.533	3.950	4.350	4.7

SECOND GROUP.

NUMBERS OF RAILS.	MAY 1872.	MAY 1873.	MAY 1874.	AUGUST 1875.
		WROUGHT IRON RAILS.		
39	Replaced in August 1869.	″	″	″
46	2.3	2.7	3.0	3.4
49	2.2	2.6	3.0	3.3
58	2.5	2.9	3.2	3.4
AVERAGES...	2.333	2,733	3.066	3.366
		BESSEMER STEEL RAILS.		
39	0.5	0.9	1.3	1.7
46	1.8	2.0	2.2	2.4
51	1.0	1.3	1.6	2.0
58	1.2	1.6	2.0	2.2
AVERAGES,..	1.125	1.45	1.775	2.075

THIRD GROUP.

NUMBERS OF RAILS.	MAY 1872.	MAY 1873.	MAY 1874.	AUGUST 1875.
		WOLFRAM STEEL RAILS.		
1	″	″	″	1.9
2	″	″	″	2.6
3	″	″	″	1.8
4	″	″	″	1.5
5	″	″	″	2.0
6	″	″	″	2.1
AVERAGES...	″	″	″	1.983

The tonnage passing over these rails from the time of laying down (1866), till the last verification of wear (August 1875), was calculated at 35,057,537 tons. The tonnage borne by the rails in wolfram steel from the time of laying down (August 1869), till the same period (August 1875), was 21.699,558 tons.

These figures establish that, for a wear of one millimetre, the tonnage was:

FIRST GROUP.		SECOND GROUP.		THIRD GROUP.
Wrought iron rails.	Bessemer steel rails.	Wrought iron rails.	Bessemer steel rails.	Wolfram steel rails.
6,614,630^{t}	7,459,050^{t}	10,415,192^{t}	16,895,198^{t}	10,942,237^{t}

2. *Duration.* — All the steel rails have resisted perfectly, and none of them have been replaced.

This is by no means the case with the wrought iron rails, since it has been necessary to replace 38 of 60 originally laid down (63 per cent).

The following table indicates the date of replacement of each rail, and the tonnage it has borne.

FIRST GROUP.			SECOND GROUP.		
NUMBER.	DATES.	TONNAGE.	NUMBER.	DATES.	TONNAGE.
1	October 1867...	6,051,934^{t}	2	October 1867...	6,051,934^{t}
2	November 1868.	9,471,343	1	November 1868.	9,471,343
1	December 1869.	14,950,774	1	May 1869.....	12,540,090
1	July 1871......	20,135,382	3	August 1869...	13,573,240
5	May 1872.....	23,598,639	1	February 1872..	22,347,908
1	September 1872.	24,533,295	1	March 1873....	26,402,606
1	November 1872.	25,156,399	1	December 1873.	29,051,805
1	September 1873.	28,168,739	1	February 1874..	29,640,518
4	November 1873.	28,757,450	1	November 1874.	32,352,517
2	December 1873.	29,051,805	2	January 1875...	32,955,183
1	July 1874.....	31,147,184			
3	August 1874...	31,448,517			
1	June 1875.....	34,461,849			
24	AVERAGE TONNAGE.	24,542,516	14	AVERAGE TONNAGE.	20,038,644

From the first group, 24 rails out of 36 were withdrawn, i. e. 66,6 p. o/o.

From the second group, 14 rails were withdrawn out of 24, i. e. 58,3 p. o/o.

The wrought iron rails used in these experiments of comparison, come from the Wendel iron works. The excellence of their quality is demonstrated by the fact that 27 p. o/o of the total number tested, have resisted a wear of 35 millions of tons, and that those past service (63 p. o/o) have supported an average of 20 to 25 millions. With respect to the steel rails, they were supplied by MM. de Dietrich and Company, but the wolfram rails come from Terre-Noire. Not a single one of these rails has been withdrawn from the lines, and the only change they have undergone, has been that occasioned by a slow and uniform wear. Albeit the first group is subjected to the incessant action of the brakes, the deterioration does not attain to $0^m,005$, and from this time it may be asserted, that only after a term of service extending over more than twenty years, will these rails require to be replaced. In the second group, which is less exceptionally situated, though still subjected to severe trial, the wear hardly exceeds $0^m,002$, and the duration of steel rails ought under similar circumstances to attain a period of not less than fifty years.

The wolfram rails from Terre-Noire wear more rapidly than the other steel rails. They are evidently made of a steel containing less carbon, so that the wolfram has not succeeded in hardening it sufficiently.

The Eastern Company has also made experiments which have confirmed, in every particular, those of the Northern Company, on the comparative resistances of steel and iron.

One of the tests for the wrought iron rails, consists in placing a bar on two supports $1^m,10$ apart, and loading it in the middle of its length, with weights which are increased till a fracture is produced. The bend of the rail under each weight is measured, as also the permanent bend that it has acquired after the removal of this weight. The following averages were obtained from 40 bars at the Stiring iron works.

WEIGHTS.	BENDING	
	UNDER WEIGHT.	PERMANENT.
$12,000^k$	$2^{mm},83$	$0^{mm},00$
15,000	4 19	0 14
20,000	11 57	6 62
25,000	36 88	29 06

Of the 40 rails experimented upon, 26 broke under a weight of 30,000 kilogrammes, 9 under 32,000, and 5 only could not be broken, the testing machinery not being constructed to support a greater load.

The momentum of inertia of the section of the rail is $I = 0,0000082$. By the introduction of this value into $E = \frac{Pa3}{48fI}$, and making $P = 12,000$ kilogrammes, formula $a = 1^m,10$, $f = 0^m,00283$, the modulus of elasticity is found, $E = 14,3 \times 10^9$. The corresponding bending moment is $\mu = \frac{12,000 \times 1,10}{4} = 3,300$ kilogrammetres.

and the strain to which the fibres most worked are subjected is $R = 3{,}300 \times \frac{n}{I} = 3{,}300 \times 7{,}560 = 24^{k}{,}9 \times 10^{6}$.

By applying the same calculations for the weight of 15,000 kilogrammes, and only taking into account the elastic bend $4^{mm}{,}19 - 0^{mm}{,}14$ there is found $E = 12{,}5 \times 10^{9}$.

Thus, although the permanent bend under a weight of 15,000 kilogrammes, is very slight, the elasticity is already changed. It follows then, that the wrought iron rail can only resist, without alteration, a bending moment of little more than 3,300 kilogrammetres, or about 25 kilogrammes per square millimetre, and its modulus of elasticity is $E = 14{,}3 \times 10^{9}$.

The steel rails are subjected to a similar test; but at the Terre-Noire works, where the trials have been made, the points of support are only 1 metre apart instead of $1^{m}{,}10$. The following averages show the result of thirty three trials :

WEIGHTS.	BENDING	
	UNDER WEIGHT.	PERMANENT.
$18{,}000^{k}$	$2^{mm}{,}61$	$0^{mm}{,}13$
20,000	2 98	0 24
25,000	5 54	2 11
30,000	12 63	8 03
35,000	22 25	20 31

Only one of the 33 rails tested, broke at 38.000 kilogrammes, as for the 32 remaining, the machinery was not sufficiently powerful to fracture them.

Under the weight of 18,000 kilogrammes, the elastic bend being $2^{mm},61 - 0^{mm},13$, there results $E = 18,4 \times 10^9$. Under that of 20,000 kilogrammes there is $f = 2^{mm},98 - 0^{mm},24$ and $E = 18,5 \times 10^9$.

Thus, under a weight of 20,000 kilogrammes the elasticity remains without alteration, though the permanent bend is appreciable, but this bend is, in fact, more apparent than real, and is partially due to as light penetration of the knife edges constituting the points of support. In the Stiring apparatus for testing wrought iron rails, the supports have not sharp edges.

The steel rails then resist, without alteration in their elasticity, a bending moment $\mu = \frac{20,000 \times 1,00}{4} = 5,000$ kilogrammetres which corresponds to $R = 5,000 \times 7,560 = 37^k,8 \times 10^6$.

By comparing the above mentioned results, it follows that:

1. Steel rails support, without alteration in their elasticity, a greater molecular strain than iron rails, in the relation of $\frac{37,8}{14,3} = 1,5$, nearly;

2. The relation of the moduli of elasticity is $\frac{18,4}{14,3} = 1,28$;

3. Nearly all the wrought iron rails fracture under a bending moment equal to $\frac{30,000 \times 1,10}{4} = 8,250$ kilogrammetres, while those in steel resist $\frac{38,000 \times 1,00}{4} = 9,500$ kilogrammetres. As the apparatus employed for testing did not possess the strength requisite to fracture the steel rails, the exact relation of resistance to fracture

cannot be expressed, but it may be seen that this relation must be very considerable.

The resistance of steel rails to shock, is also much greater than that of wrought iron rails. The latter are tried by means of an apparatus composed of two cast iron supports, distant from each other $1^{m},10$, and resting on an oaken frame, supported by a solid mass of stonework. A cast iron monkey, 300 kilogrammes in weight, is let fall upon the middle of the rail between the supports, and the height of the fall is increased until the rail is fractured.

The following results have been established at la Villette, by means of an apparatus established under these conditions:

Six Vignoles rails were each cut into two half-rails 3 métres in length, and each half was tested under falls from heights of $0^{m},25$, $0^{m},50$, and $0^{m},75$ successively.

The tests have been made both in winter and summer, in order to ascertain the effect of the different temperatures upon the resistance to shock. The heights for the fracture of the two halves of each rail are given below:

Winter....	$1^{m},00$	$0^{m},75$	$1^{m},25$	$1^{m},75$	$1^{m},00$	$1^{m},50$
Summer...	$1^{m},25$	$1^{m},75$	$1^{m},25$	$2^{m},50$	$2^{m},50$	$2^{m},50$

Winter average...	$1^{m},21$.	Average temperature..	— 8°
Summer average..	$1^{m},96$.	Average temperature..	+ 26°

The steel rails are subjected to a trial much more severe. The monkey weighs 300 kilogrammes and the supports are $1^{m},10$ apart, as for the wrought iron rails. But these supports include, and make one, with a cast iron anvil 10,000 kilogrammes in weight, founded on the masonry. Commencing at $1^{m},10$, the heights of fall are increased by $0^{m},50$.

Of thirty three cast steel rails tested at Terre-Noire, 1 was fractured at $1^{m},50$, 1 at 2 metres, 2 at 3 metres, 7 at $3^{m},50$, 1 at 4 metres, 4 at $4^{m},50$, 1 at 5 metres. The remaining rails to the number of sixteen, resisted the greatest height of fall that the apparatus was capable of giving.

Similar appliances enabled the Northern Company to institute a comparison between their new type of steel rail, weighing $30^{kg},3$, and the old wrought-iron rail of $37^{kg},2$. The results obtained were analogous. The weight of the monkey did not exceed 200 kilogrammes; but the other arrangements resembled those at Terre-Noire. The heights of fall were successively 1 metre, $1^{m},50$, $1^{m},70$, 2 metres, $2^{m},50$, 3 metres, $3^{m},40$. Eleven steel rails out of twelve resisted the maximum height; only one yielded at $3^{m},40$, and in this instance, a defect was observed in the foot, at the section of fracture. Fourteen iron rails being tried in the same manner, 1 was broken at 1 metre, 3 at $1^{m},50$, 3 at $1^{m},70$, 1 at 2 metres, 2 at $2^{m},50$, 2 at 3 metres, and two only resisted at $3^{m},40$. Notwithstanding the difference of section, the absolute relation of average heights of fracture exceeds 1,56. Allowance being made for this difference, it will be found that the relation of resistance to fracture, between the steel and the wrought iron, exceeds $1,56 \times 1,18 = 1,84$.

These results induced the Eastern Company to consider the expediency of adopting a Bessemer steel rail of reduced section, as the Northern Company had previously done. The rail was submitted to the inspection of the Government, and by a decree of the 18th January 1873, the Eastern Company was authorized to make use of steel rails weighing 30 kilogrammes per metre.

The new steel rail of the Eastern Company has a normal length of 8 metres. The joints are fished alternately and crossed $0^{m},60$, so that the joints of one line of rails do not correspond to those of the other. Experience has demonstrated that this arrangement conduces to the stability of the joint sleepers, and to the regularity of laying down in curves, also that it lessens the shocks due to the solution of continuity and to the slight deflection arising therefrom. The number of intermediate sleepers, since the joints are alternate, is nine per rail of 8 metres. Sliding in a longitudinal direction, is prevented by iron wedges fixed to the sleepers, and meeting the ends of the fishplates; thus there is no scarf in the foot of the rail, and consequently the great weakening, which every hollow causes to the steel rail, is entirely avoided.

All these arrangements are given in the drawing exhibited, to which is added a pattern showing the section of the rail.

Up to the present time, the length of line laid down with rails of this type is 75 kilometres. The orders in course of execution, are equal to a development of 740 kilometres.

PARIS, LYON AND MEDITERRANEAN RAILWAY COMPANY.

1. MODEL PM.

From the year 1867, the Paris, Lyon and Mediterranean Railway Company had decided to employ steel rails only, in re-laying their lines from Paris to Marseille, a distance of 860 kilometres. During a year the number of trains on each line exceeds 10,000, at degrees of speed attaining to 90 kilometres an hour.

At the commencement of 1876, the length of the portions re-laid, was already 1,450 kilometres of single line.

Arrangement of the line in rails on the PM model. — The rail exhibited (PM model) weighs 38^{kg},850 per metre. A wrought iron rail (model PLM) is used on all the new Mediterranean lines, and the rail in question only differs from it in thickness of web, which is reduced from 16 to 14 millimetres, and in breadth of foot, which is increased from 100 to 130 millimetres.

In both types the head and foot have the same distance and inclination, and are thus adapted to the same fish-plate.

The normal length of the rail is 6 metres, and it is laid on eight intermediate sleepers, and with the joints not corresponding.

Fishing. — Each joint is consolidated by two wrought iron fish-plates with four holes, and connected by four wrought iron bolts 25 millimetres in diameter, with two screw nuts to each. An iron spike which fits into a groove contrived under the middle of the fish-plate and under the lower side of the screw nut, prevents the nut from unscrewing.

Method of fastening.—The rail is fixed to each sleeper:

1. On the inside of the line by a chair-pin with two hooks or claws, fitted into a hole in the foot of the rail, in order to prevent the rail sliding in the direction of the line, at the same time to hinder it from canting;

2. On the outside of the line by a cramp with one claw.

2. MODEL PLM-A.

On the other lines, where the traffic is not so important as on that from Paris to Marseille, the Paris, Lyon and Mediterranean Company has employed, since 1872, a rail lighter than the preceding one.

At the commencement of 1876, the length of lines relaid or formed with this second model, attained to 878 kilometres of single line.

Arrangement of line in rails on the PLM-A model. — The rail exhibited (model PLM-A) weighs $33^{\text{kg}},30$ per metre. Its section is essentially that of the wrought iron rail (PLM model), in breadth of foot, depth, and breadth of flange, position of fish-plates, etc. It only differs from it in thickness of web, reduced from 16 to 12 millimetres. and in thickness of foot, which is reduced 2,5 millimetres.

The normal length of the rail is 6 metres and it rests either directly, or by the medium of a bed-plate, on six, seven, and in some cases, eight sleepers.

The two sleepers on either side of the joint are always fitted with bed-plates.

Fishing. — Each joint is consolidated by two wrought iron fish-plates with four holes, connected by four bolts.

One of the fish-plates is on the same model as that employed on the line PM; the second designated as fish-stop-plates, extends below the plane of the rail foot, in such a manner as to meet the bed-plates laid on the joint sleepers, and thus prevent a movement or shifting of the rail.

The bolts of the fish-plates, and the iron spike that keeps the nut from unscrewing, are the same as on the line PM.

Method of fastening. — The rail is fixed to each sleeper by means of two screws placed on the edge of the rail-foot. The foot is neither pierced nor scarfed.

Manufacture. — The rails PM and PLM-A are made at the works of Creusot, Terre-Noire, Bessèges, Firminy, Saint-Étienne, Imphy and Commentry, either in Bessemer or Martin steel.

Whatever may be the method employed in the manufacture of these rails, they easily resist the conditions of trial hereinafter mentioned, and the results obtained at the various ironworks show no appreciable difference. However, in some, the Martin steel appears a little harder than the Bessemer, while in others the Bessemer steel has the advantage.

Tests for service. — One per cent of the rails manufactured, are subjected to the following tests:

1. Each rail placed on two points of support, one metre apart, must bear, during the space of five minutes, in the middle of the interval between the points of sup-

port, a pressure of 25 tons for the rail PLM-A, and 30 tons for the rail PM, without retaining any appreciable bend after the trial.

2. The same rail, in the same position, must bear for five minutes, without fracture, a weight of 35 tons for the rail PLM-A and 40 tons for the rail PM; afterwards, the pressure is increased until the rail is fractured.

3. Each of the halves of the rail, placed on two points of support 1^{m},10 apart, must bear without breaking, the shock of a monkey 300 kilogrammes in weight, falling from a height of 1^{m},70 for the rail PLM-A, and of 2 metres for the rail PM, on the middle of the interval between the supports, and without retaining, after this test, a permanent bend of more than 8 millimetres.

4. A clean strip, 70 centimetres in length, is to be chosen from each casting, and to be placed on two supports 50 centimetres apart. It must bear without breaking, the shock of a monkey 300 kilogrammes in weight, falling from a height of 1^{m},30 for the rail PLM-A and of 1^{m},50 for the rail PM.

Results obtained with steel. — Up to the present time the experiments have given the following results:

The wear of steel rails proceeds regularly and in proportion to the accumulated strain, or to the number of trains passing over the lines.

On an average, this wear may be estimated at 1 millimetre for 50,000 trains.

The flange of the rails PM and PLM-A can, without being too much weakened, be re-cut or permitted to wear away uniformly to the extent of more than 10 millimetres.

There is therefore reason to suppose that the passage of 500,000 trains would be required to put the steel rails past service.

Taking fairly into account, accidents and the possibility of mistakes, if only 400,000 trains are admitted as the limit, and on the other hand, if it is remembered that the average duration of iron rails, under the same conditions, corresponds to the passage of 80,000 trains, the conclusion is inevitable, that steel rails must be considered capable of lasting at least five times as long as those in wrought iron.

Broken rails. — The average number of rails broken, so as to render it necessary to withdraw them from the lines, is one rail per year for every 15 kilometres of line. For the most part, the fractures take place within the first few days of the laying down and use of the rail, and must frequently be attributed to a defect in the manufacture. After a resistance of some months, it may be considered that the steel rail is beyond the reach of accident, and cannot be broken.

Cost price. — At the present price of metal (February 1876), the kilometre on a single line in steel (metallic part) costs:

1. LINE PM MODEL.

77,700 kilogrammes of rails at 240 francs per ton...	18,648^{f}	00^{c}
666 fish-plates (weight 5^{k},30) at 190 francs per ton..	670	66
1,332 bolts (weight 0^{k},70) at 350 francs per ton.....	326	34
2,664 chair pins (weight 0^{k},41) at 340 francs per ton.	371	36
2,664 cramps (weight 0^{k},39) at 340 francs per ton..	353	25
Total.............	20.369^{f}	61^{c}

2. LINE PLM-A MODEL.

66,600 kilogrammes of rails at 240 francs per ton...	15,984^{f} 00^{c}
333 fish-plates PM (weight $5^{k},30$) at 190 francs per ton.	335 33
333 fish-stop-plates (éclisses-arrêt) (weight $7^{k},58$) at 200 fr. per ton.	504 83
1,332 bolts (weight $0^{k},70$) at 350 francs per ton.....	326 34
999 steel bed-plates (weight $1^{k},83$) at 260 fr. per ton.	475 32
3,996 iron screws (weight $0^{k},36$) at 420 francs per ton.	604 20
Total..............	18,230^{f} 02^{c}

The four patterns exhibited, come from the iron firms designated above.

Note. For details see the tickets on each of the rails.

SOUTHERN RAILWAY COMPANY.

The Southern Railway Company employs steel rails on the principal lines of their system.

These rails are made either on the Bessemer or the Martin plan, and are supplied by the various French iron works that have set up the machinery necessary for their fabrication, viz. Imphy, le Creusot, Terre-Noire, Firminy and Commentry.

With some rare exceptions, the steel rails employed on the Southern lines, are all double-headed, and their form is the same as that in use for ordinary rails.

Normal length of rail..............................	$5^{m},50$
One tenth of rails supplied....	$5^{m},46$
Distance of sleepers from joint......................	$0^{m},60$
Distance between intermediate sleepers...............	$0^{m},98$
Rail in Martin steel from the works of the anonymous society of steel works and forges of Firminy. — Manufacture in 1872..................................	$38^{kg},000$

(The Company has also employed rails of the same section in Bessemer steel from the works of Terre-Noire and of Bességes.)

Chairs from the iron works of Marquise (Pas-de-Calais). — Manufactured in 1869. — Weight of a chair	10^{kg},200
Chair-pins made at the Dervaux works at Vieux-Condé (Nord) en 1872. — Weight of a chair-pin	0^{kg},440
Wedges supplied by M. Bastiat, of Dax (Landes). — Manufactured in 1872. — Weight of a wedge	0^{kg},900
Fish-plates from the Alais works. — Manufactured in 1873. — Weight of a pair	9^{kg},100
Fish-bolts manufactured at the works of M. Vankalck, near Valenciennes, 1873. — Weight of a bolt	0^{kg},445
Brunel hollow rail in Bessemer steel for turn-table, from the works of Terre-Noire (Loire). — Made in 1870. — Weight per metre run	34^{kg},500

Length laid, up to the 31st December 1874 : 73^{km},556^{m}.

ORLEANS RAILWAY COMPANY.

The Orleans Railway Company makes use of steel rails on those sections of their lines where the traffic is the most important.

These rails, manufactured either by the Bessemer or by the Martin process, are supplied by the various French firms that have set up the apparatus necessary for these systems, viz. Imphy, le Creusot, Terre-Noire, Firminy and Commentry.

With some rare exceptions, the steel rails employed on the Orleans lines are all double headed, and the shape does not differ from that in use for ordinary rails.

The weight of rail per metre is 36 kilogrammes for those in wrought iron, while for steel it is a little more, in consequence of the different density of the two metals, and may be calculated at an average 37 kilogrammes.

The rails are 5^{m},50 in length, and are fished with alternate joints. They rest on six oak sleepers, by the medium of cast iron chairs, and this arrangement gives an average distance between each sleeper of $\frac{5^{m},50}{6} = 916$ millimetres.

The chair weighs $9^{kg},50$, and has a base surface of 324 square centimetres.

WESTERN RAILWAY COMPANY.

The Western Company makes use of steel rails on their most important lines. Up to the present time, the rails employed have been supplied by French firms, viz. Niederbronn, Imphy, le Creusot, Terre-Noire, Firminy and Commentry, and have been manufactured by the Bessemer and Martin processes. At the commencement, a small quantity were fabricated in steel cast in the crucible.

The length of single line laid with steel rails at the close of 1875, had attained to 500 kilometres.

With the exception of the Vignoles rails, employed on the great lines, the steel rails are of the double headed type, and are the same in section as the wrought iron rails.

Their average weight is $38^{kg},75$ per metre run, or 1 kilogramme more than the wrought iron rails, which weigh $37^{kg},75$.

The rails are 6 metres in length, and are fished with alternate joints; the fish-plates employed with the steel rails, are also in steel.

Through the medium of cast iron chairs, the rails rest on eight sleepers, 6 metres in length. They are separated from each other as follows:

The first chair is placed at a distance of $0^{m},30$ from the extremity of the rail;

The second is placed $0^m,70$ from the first;

And the others at $0^m,80$, one from the other, from centre to centre.

The cast iron chairs weigh 15 kilogrammes, and present a base of 482 centimetres square.

The chairs are fastened by means of two screws, in the straight parts of the line, but for the curves, three are used for the row of rails on the greater radius; there are also two different models of chairs.

During the year 1874, it was decided to adopt a Vignoles rail, weighing nearly 30 kilogrammes per metre run, for the construction of new lines. The model selected, is conformable to the type employed by the Northern Railway, with the exception however of the arrangement of the fishing, which is to be alternated.

Considerable orders, representing more than 500 kilometres of line, have been given, and can be executed and delivered during the ensuing years, when required by the lines now in course of construction.

XV

COLLECTION OF LITHOGRAPHED TYPES.

OF THE PLANT AND ROLLING STOCK

ADOPTED

BY THE PRINCIPAL FRENCH RAILWAY COMPANIES.

Portfolios of drawings.

In 1867, the great railway Companies exhibited a collection of types of their plant and rolling stock in general use at that period.

This collection, to which are constantly added the modifications suggested by experience, constitutes an assemblage of lithographed drawings which possesses the merit of presenting with accuracy the existing state of the plant of the principal Companies.

It has been thought that a review of the alterations that have taken place during a period of nine years, would not be devoid of interest, and that the various improvements necessitated by the great development of French lines of railway, would be worthy of the attention of professional men.

It is not intended to describe in this notice the numerous drawings contained in the collection, but simply to place in view the principal peculiarities of the French plant and rolling stock, and to furnish a few succinct ideas relative thereto: 1. with regard to the line upon which the plant is employed, and 2. the working arrangements.

S I, Permanent way.

Limit of curves and gradients. — When railways were first established in America, the country was, so to speak, new, and comparatively unprovided with lines of communication. This was not the case in France, where the special functions of this novel method of locomotion were to realise, in connection with the ordinary roads, on the one hand, an accession of speed for travellers, and on the other, a considerable saving in the transport of goods. At the commencement of railways in France, some of the leading principles of the English lines were adopted, in respect of light gradients and large curves, but later, the rules first laid down, were departed from to a certain extent, in order to lessen the cost of construction in hilly districts. Nevertheless, curves of 300 metres, and gradients of 30 to 35 millimetres, are still the extreme conditions, and these are only met with under circumstances of an exceptional character.

Permanent way laid under favourable conditions. — The permanent ways in France are distinguished by the substantial character of their construction. The necessity and advantages attending this feature of their establishment, were recognized at an early epoch in the history of French railways. In fact, from May 1847, rails of 27 kilogrammes were replaced by rails weighing 35 to 37 kilogrammes per metre run, and since that period, the conditions of railway concessions have always enjoined for the principal lines, a weight of more than 35 kilogrammes per metre. One metre was for a long time the average space between the points of support, that is to say, one sleeper per metre run. But for lines upon which the traffic is the most considerable, the distance between the sleepers has been greatly reduced, as can be seen by referring to the notices relating to lines recently laid with steel rails.

The whole of the permanent way rests on a bed of good ballast, the thickness of which, measured from the lower face of the sleepers, is generally 30 centimetres.

§ II. — CROSSINGS.

SIGNALS AND ACCESSOIRES.

Crossings and sidings. — The switches are nearly all on the English model (*Wild's system*), in which the tongue diminishes in size and, terminating in a point, identifies itself with the rail.

All the parts are now made of steel. In laying the crossings, there exists a marked tendency to do away with the frame or longitudinal sleepers, and to substitute cross sleepers as nearly similar as possible to the ordinary way.

The transmission of the switch movement to a distance, is in course of experiment on some lines.

Turn-tables and traversers. — The ordinary turn-tables for carriages, are generally made of cast iron, while those of 10 to 14 metres in length, intended to bear an engine with its tender, are usually formed of two iron plate girders, and moved by small portable engines of 2 to 6 horse power.

The shed traversers are also frequently furnished with small engines, and steam traversers are in course of trial for the service of certain great goods stations.

Water supply, hydrants. — Formerly, the water was supplied by means of engines with fixed boilers, that is to say, laid in masonry. But it has been found more advantageous to employ a portable engine, partially fixed, and capable of being easily changed or conveyed to the shed for necessary repairs. The Northern Railway Company even uses the ordinary portable engine mounted on wheels, and working the pumps by means of a driving belt.

The ordinary hydrants are not adequate to the supply of large engines, during the short space of time allowed for the stoppage of an express train, and it is now a considerable time, since the Northern Company substituted for the ordinary hydrant a small reservoir, containing 6 or 7 cubic metres, communicating with the large reservoir and discharging itself promptly. This example has been followed by other lines, and notably so by the Western Company, whose reservoir mounted on cast iron pillars, is worthy of attention.

Station signals. — The Government regulations ordain the use of signals at all stations. For the most part they consist of round sheet iron discs, turning on a wrought iron spindle, in such a manner as to show at discretion, a red side, commanding the stoppage of trains. These discs are worked at distances of from 1,000 to 1,500 metres, by means of levers and iron wires. The most serious difficulty to surmount, was the difference in the length of the wires caused by dilatation. This problem has been solved in a satisfactory manner by various means shown on the drawings furnished by the Companies. One arrangement, which is being generally adopted, is that of a counter-poise, ***Robert's system,*** and is much used on the Northern Railway.

The distance discs are not visible from the manœuvring point, and are connected by electric bells in order to announce the correct working of each.

The Lyon Railway uses semaphores, placed in the interior of the stations, and at several points on the line, to preserve a proper distance between the trains. The Orleans Railway employs for the same purpose a special round disc.

Signals of a yellow-colour are used in certain cases for the lines or for goods trains.

In the interior of the great termini, it is often necessary to establish a communication between the different switch-boxes, and this is effected by electric apparatus; or more frequently by small discs of various shapes, worked by wires, but having no significance for the engine-drivers.

It may be noticed that wrought and cast iron have been substituted for wood, in the uprights, frames, and other parts of the apparatus.

Junction signals. — The junction lines are protected in all directions by a system of signals, the working of which, is combined so as to avoid collisions. The Northern Company, for example, places in advance of the points of junction a special square indicator, quartered in green and white, at sight of which the engine-driver is to slacken speed. In addition to this, a square red signal, furnished with a petard or detonator, is placed at a distance of 100 metres from the point of crossing. This signal commands the *absolute stoppage* of trains.

The Lyon Railway gives warning of the approach to a crossing by means of a transparency, bearing the word *stop*, which indicates the point not to be passed, when the line is not clear. This latter signal is made from the post of crossing, by two unequal semaphores, the largest of which has reference to the main line, and the other to the branch.

In order to distinguish, at night, the absolute stoppage signal from the simple safety disc, the Western Company makes use of a lantern in which a single lamp shows *two red lights* by means of reflectors suitably arranged.

Interlocking of switches and signals. — From 1854, M. Vignier, one of the engineers of the Western Railway Company, proposed to connect the levers of the switches with those of the signals. Iron connecting rods, moved by the levers themselves, are fitted with notches or ring-hooks combined so as to *interlock* both. With this contrivance a junction cannot be formed by the switch, nor can a train cross another line, until the proper signal has been made. This method of interlocking is also to be recommended in the case of signals protecting the turn-tables.

This system was applied for the first time at the Viroflay junction near Versailles, and being in general use on the Western Railway, will probably be adopted throughout France. During these latter years it has been employed on the English railways, notably by the celebrated constructors Saxby and Farmer.

Blocking of trains. — On the most important lines, great advantage has resulted from the plan of putting an interval of distance between the trains, instead of an interval of time. For this purpose, the line must be divided into a certain number of *sections*, into each of which only one, or at most, two trains are admitted. This is the English *block-system*, which affords greater facilities for the traffic while it assures the safe working of a double line.

The block-system is employed on various lines in France. The Lyon Railway Company makes use of the station distance signals, for this purpose, adding the English Tyer apparatus. The Western Company has boxes furnished with distance and complete stoppage signals. The electric apparatus employed, is due to M. Regnault, one of the principal managers of the line.

The Northern Railway is testing the semaphores of M. Lartigue, inspector of the telegraphic service, and an experiment is being made between Paris and Creil, a distance of 50 kilometres. In this system, a single movement of the lever, signals to the preceding station, and conveys at the same time, the necessary indications to the station towards which the train is proceeding.

Fog signals. — During a fog the engine-drivers cannot see the signals from a distance, and to remedy this inconvenience, the Northern Railway has put upon trial a system of MM. Lartigue and Foret. A metal plate, 4 or 5 metres in length, is placed between the rails, some hundreds of metres in advance of the signal, with which it is connected by an electric wire. A strong wire brush is fixed to the locomotive, in such a manner as to rub the fixed plate. When the disc is closed, the brush is subjected to electric influence, and by means of an electro-magnet it sounds a small steam-whistle. It then behoves the engine-driver to take immediate steps for the stoppage of the train.

ROLLING STOCK.

§ I. — ADAPTATION OF THE ROLLING STOCK TO THE NATURE OF THE LINES AND THE TRAFFIC FOR WHICH IT IS REQUIRED.

The general conditions of the establishment of the permanent way have been dwelt upon at some length, in order to demonstrate that they are in perfect accordance with the rolling stock intended to circulate upon the lines. The carriages are of the English type, that is to say, with two or three rigid axles, which would not permit a great degree of speed in curves with small radii. On the other hand, in an economical point of view, as regards the working, this system has afforded, up to the present time, the advantage of the greatest absolute utility, or in other words, the smallest dead weight in proportion to the load carried.

§ II. — TRAFFIC.

Nature and speed of trains. — The condition of canals in France and the arrangement of navigable ways, still leave to railways the transport of a large proportion of heavy materials and agricultural products, viz. coal, minerals, stone, cast and wrought iron, wine, grain, etc. The goods trains are generally heavy, and run at the slow speed of 25 kilometres per hour, average rate, not including stoppages. The cattle trains most frequently travel 30 kilometres per hour.

The conveyance of goods at full speed, is effected by ordinary or mixed passenger trains, at a rate of from 40 to 50 kilometres per hour, stoppages not included.

And finally, the fast or express trains attain a speed of 60 to 75 kilometres per hour, according to the importance of the direction.

On branch lines, where the traffic is of less importance, the trains are generally mixed, carrying goods and passengers at the same time, with an average speed of from 35 to 45 kilometres per hour.

Composition of passenger trains. — It is known to all engineers that European railways admit of three classes of passenger carriages. In France, mixed trains consist of carriages of all classes. Express trains were from the commencement exclusively composed of first class carriages, but at the present date there exists a strong feeling in favour of the addition of a second, and even of a third class, for long distances. This innovation is already an accomplished fact on certain lines and for certain trains.

The preceding statements having sufficiently indicated the principal conditions of the establishment and working of French railways, they will now be followed by a description of the rolling stock of the lines.

S III. — CARRIAGES AND WAGONS.

Advantages of the French plant in the favourable relation of dead weight to actual load carried. — Of all plant constructed on the English type, the French presents the most perfect realisation of utility, and in order to facilitate comparison, some examples, in a synopsis of dead weight and actual load, will be given at the end of this chapter.

This small relation between dead weight and actual load must not be placed merely to the credit of excellence of construction, but also to a judicious appreciation of the load or carrying capacity. Since 1852, the Northern Railway, having to run coal trains direct between Belgium and Paris, a distance of more than 300 kilometres, substituted wagons containing 10 tons for those carrying 6, and the dead weight per ton of actual load was diminished from 550 kilogrammes to 400. At the same time locomotives with six coupled wheels, were constructed for the same service, weighing 32 $\frac{1}{2}$ tons, and drawing trains of 420 tons gross, at a speed of 24 kilometres per hour, on lines with gradients of 5 millimetres per metre. At the present day these trains weigh 630 tons, and are drawn by locomotives with eight coupled wheels weighing from 40 to 44 tons. Various circumstances, relating to the loading and unloading on the coal lines or stations, have caused the retention of this load limit of 10 tons, but there are strong reasons for believing that this figure will eventually be augmented to 12 or 15 tons, without increasing the number of axles, as soon as the rails on the principal lines are replaced by steel rails.

Carriages of passenger trains. — The passenger carriages have all 4 wheels, except on the principal lines of the Paris, Lyon and Mediterranean Company, where 6 wheels are used.

It has been already stated that there were three classes of carriages.

First class carriages have 8 seats in each compartment. The second and third class have 10. The third class carriages have no cushions or back stuffing, and the backs are more or less high, without reaching the top of the carriage, except in the compartments reserved for ladies only.

First class carriages most frequently consist of 3 compartments, the second class of 4, and the third of 5. In order to secure the stability of carriages, when travelling at a high rate of speed, their length has not been increased in proportion to the distance of the axles from each other.

The distance between axles has reached its limit; not according to the radii of curves, but owing to the dimensions of the turn-tables generally employed in the formation of trains in the stations. The distance between the axles is $4^{m},10$ and 4 metres, on the Lyon, Northern and Western Railways, while on other lines it is $3^{m},60$ on the average. At the present time a reaction is operating against the constraint arising from the size of the turn-tables, and the means of obviating this inconvenience are in course of consideration, at least for trains going long distances, without separating.

The carriages are connected by means of screw couplers, acting upon springs which bring the *buffers* into contact and press them together in such a manner as to avoid the movement of oscillation. Two chains, called safety chains, complete the coupling, which is *uniform for all the carriages.*

The body of the carriage rests on a frame, for the side pieces of which, iron is coming more and more into general use. The Lyon Company constructs the frame entirely of iron.

The axles are of wrought iron, and more rarely, of soft steel. The wheels are of three kinds: 1. Wheels in wrought iron with a cast iron nave; 2. Entirely in forged iron (Arbel type); 3. In rolled iron with the shape of a complete disc, in order not to raise the dust.

Cast iron wheels are not used.

The tires are in wrought iron or soft steel.

The greasing is usually effected by means of oil boxes.

In addition to the general arrangements, of which mention has been made, various combinations exist, answering to special requirements, and which deserve notice.

(A) *First class carriages* provided with *coupés* or compartments capable of being converted into beds during the night;

(B) *Sleeping carriages* on four wheels (Mann's system), in which the introduction of «sleeping-cars» something like those used in America, has been attempted on a small scale;

(C) *Carriages* open or closed, with roof seats, for the service of the suburban lines of Paris, or the different branches;

(D) *Carriages* with compartments of different classes, for the service of the small branch lines;

(E) *Carriages* with a central or lateral passage, adopted on secondary lines, with the view of facilitating the examination and even the delivery of tickets during the journey, etc. etc.

(F) *Travelling* post offices, special wagons.

Certain vehicles form part of each train, and always run at the speed of passenger trains. These are the luggage vans, in which the guard travels, and the horse boxes for the transport of horses, and capable of containing from 3 to 7 of these animals.

The establishment of a *communication between the passengers and the persons managing the train,* has not hitherto admitted of a definitive solution. Some experiments are being carried on by the Northern Railway Company, and thus far, the results appear satisfactory. The apparatus employed, consists of electric communication arranged according to the Prudhomme system.

Goods wagons. — The general conditions of coupling, frame, wheels, etc., are the same as for passenger carriages. There are three principal types of goods wagons, viz.

(I) *Covered wagons,* with windows most frequently closed by means of sheet iron shutters. Their load limit varies from 8 to 10 tons according to the traffic of the lines;

(II) *Trucks,* with sides $0^m,80$ to $1^m,20$ in height, for the transport of coals, minerals, etc. Their carrying capacity is 10 tons;

(III) *Open trucks,* sometimes without any sides, but generally with a movable hinged side $0^m,30$ in height, capable of being lowered at discretion. Their carrying capacity is in general 10 tons. These trucks are furnished with ropes (*called prolonges*) for securing the goods, and sometimes with tarpaulins to protect them from the weather. A certain number of open trucks are appropriated to the transport of long timber, and for this purpose, they are fitted with a transverse piece of wood, turning on a pivot fixed in the centre of the truck. The ends of the timber rest on this cross piece, and vertical iron bars keep them in position.

Brakes. — The adoption of two axles only, for one vehicle, enables the brake power to be adjusted upon principles of great simplicity. The most recent improvements tend to accelerate the action of the brake, by a careful study of the proportions between the screw and the various levers; also by enabling it to be more rapidly withdrawn. In these respects, attention will be directed to the *brakes on Stilmant's system* (Charentes or other carriages), or to those of the passenger carriages and goods wagons of the Western Company. The *counter-poise brakes* on Bricogne's system should also be noticed. These last are in use on the Northern Railway; the counter-poise accelerates the action of the brake blocks, and the wagon brake next to the locomotive, can be thrown out of gear by the engine-driver. The counter-poise and disconnecting gear have also been adapted by M. Bricogne to Newall's continuous brake system, which thus enables one man to apply the brake to three carriages or wagons.

§ IV. — LOCOMOTIVES.

The conditions under which the permanent way was established, preclude the necessity of employing the bogie or movable fore-part, which is not used on any engine in France. Locomotives have, for the most part, 6 wheels, placed under the cylindrical body of the boiler. The fire-box usually overhangs, as the nature of the fuel consumed is such, that only grates with a surface varying from 1 metre square to $1^{m},60$ are employed. Nevertheless, the Northern Railway lines being in close proximity to Belgium, the Company found it expedient to burn small coal, and consequently their grates were made with a surface of from $1^{m},50$ to $2^{m},50$ square, the fire-box being above the trailing axle of the engine. The fuel employed is almost always coal, very rarely coke, and at the present time all the companies burn *conglomerated* fuel, i. e. small coal mixed with pitch and compressed into the form of bricks.

Free wheel locomotives. — These engines have been much used for fast trains, and are divided into two principal types, of nearly equal number, viz.

(I) Engines on Crampton's system (Northern, Eastern, and Lyon), in which the large driving wheel, having a diameter of from $2^{m},10$ to $2^{m},30$, is placed behind the fire-box;

(II) Engines on the Stephenson model, in which the driving wheel is in the middle, the third pair of wheels being behind the fire-box. On this model are made the inside cylinder (Lyon) and outside cylinder engines, the former having the frame altogether inside (Eastern, Southern, and Orleans), while the latter have a double frame (Orleans, Western, and Northern).

Locomotives with 4 coupled wheels. — The use of this description of engine was at first confined to mixed trains, but it has since been adopted for express trains. All sorts of models are in use. There are some in which the coupled wheels are placed in front, but in general, it is considered better that a pair of free leading wheels should occupy that position, in order to guide the engine. On their principal lines, the Orleans and Lyon Railways use express engines on the inside cylinder model, for which a fourth axle, with a pair of leading wheels, is placed behind the fire-box, thus securing the perfect stability of the locomotive. The Western and Northern Companies also prefer the inside cylinder engine.

Locomotives with 6 coupled wheels. — At the present time, these are almost always made on the outside cylinder model, and, in working order, weigh 36 $\frac{1}{2}$ tons. A few light engines, of 30 tons, are still constructed, and are employed for mixed trains on branch lines. Nevertheless, certain lines pass through districts so uneven and hilly, though forming sections of the principal railways, that ordinary passenger trains have to be drawn by powerful engines; and it is for such work that the Orleans and Southern Companies employ locomotives weighing from 34 to 36 tons, with 6 coupled wheels 1^{m},60 in diameter.

The greater number of the tank engines allotted for station duty, namely, the formation and separation of goods trains, have 6 coupled wheels. The dimensions of this description of locomotive are very limited, and it is principally used on secondary lines.

Locomotives with 8 coupled wheels. — These engines are in general use on all the principal lines, except the Western. By the Northern Railway Company, they are employed to draw heavy trains carrying full loads and going long distances. On the Orleans and Lyon Railways, they are reserved for service in the difficult or hilly sections. On the Eastern and Southern lines they serve for both purposes. All have their machinery and cylinder outside.

Special locomotives. — In the department of Cantal, for a mountain line on which the gradients are 35 millimetres, the Orleans Company has had tank engines constructed with 10 coupled wheels, and weighing 60 tons when at work. One of these engines was shown at the Exhibition in 1867.

In another order of engines, may be mentioned those on Meyer's system, on the Hérault railway. This line is laid with rails of 25 kilogrammes per metre run, and comprises gradients of 25 millimetres, and curves with a radius of 200 metres. These locomotives weighing 50 tons each (fuel and water included), consist of a single boiler resting on two trucks, each having a pair of cylinders and 3 coupled axles.

General remarks on the constituent parts of the locomotive. — The system of interior frames with outside cylinders and movement, prevails in the majority of engines. The frame-work is composed of side girders of plate iron rolled in one piece.

The wheels are always in forged iron, and most frequently with steel tires. The employment of steel has become general for many of the constituent parts of the locomotive.

The use of balance beams for the bearing springs, is only beginning to be introduced on some lines.

The boilers are in iron plate, with copper fire-box and brass tubes. Some have been made of cast steel plate, by way of experiment. Before its use upon the line, every boiler is subjected to the test of hydraulic pressure, and the trial is made in presence of a Government official. This test is repeated every time the boiler undergoes important repairs.

The Government also enjoins the adoption of certain measures and precautions of safety. Such for example as, a grating or spark-catcher, to prevent the escape of fire-flakes from the smoke-box; an ash-box to keep the cinders from being scattered along the line, to the great danger of fire; a glass water-gauge and cocks indicating the level of the water, and finally, two safety-valves.

The practice of allowing a variable escape of steam from the valves, is general, as also the substitution of Giffard's injectors for one or even two pumps.

Consumption of smoke. — About 1855, when the locomotives commenced to burn coal, various plans were tried with a view to the consumption of smoke, but the experience acquired by the stokers and the selection of suitable fuel, have rendered these arrangements superfluous. On the Eastern and Orleans lines some fire-boxes on the Tinbrinck system may still be found. The air introduced into the fire-box, meets an inclined boiler-tube and mixes with the heated gases. On the Lyon Railway, a series of small jets of steam accomplishes the same object. They issue from a pipe placed in the interior of the fire-box, above the door, after a plan patented by M. Thierry.

Reversing movement of screw and brake effected by means of steam. — During the last few years, the reversing levers have been replaced by screws, moved by a fly wheel. This arrangement permits the stoppage to be effected by reversing the steam, and has been skilfully combined with the discharge of a jet of water or steam into the exhaust. By this means speed can be slackened during the descent of long gradients, by employing reversing steam, on the system of M. Le Chatelier.

SYNOPSIS OF DEAD WEIGHT OF THE VARIOUS VEHICLES IN RELATION TO ACTUAL OR PAYING LOAD OF 1 TON.

DESIGNATION OF VEHICLES AND THE LINES ON WHICH THEY ARE USED.		DATE of CONSTRUCTION.	NUMBER OF SEATS.	WEIGHT OF LOAD in kilogr.	TARE or DEAD WEIGHT of vehicle.	WEIGHT OF VEHICLE for 1 ton of actual load.
		Model	Seats	Kilogr.	Kilogr.	Kilogr.
	§ I. Passenger carriages and luggage vans.					
1st class.	*Orléans* : Frames in wood.	1867	24	1,440	6,200	4,300
	Charentes : Side pieces in iron................	1870	24	1,440	6,200	4,600
	Paris-Lyon-Méditerranée : Frame in iron (6 wheels).	1873	28	1,680	9,000	5,400
2nd class.	*Western* : Frame in wood.	1872	40	2,400	6,400	2,700
	Western : Frame in wood with imperial........	1870	70	4,200	7,400	1,800
	Paris-Lyon-Méditerranée : Frame in iron........	1873	40	2,400	7,400	3,500
3rd class.	*Northern* : Side pieces in iron................	1873	50	3,000	6,300	2,100
	Paris-Lyon-Méditerranée : Frame in iron........	1873	50	3,000	6,900	2,300
	Western : Frame in wood with imperial........	1864	86	5,160	7,000	1,350
	Eastern : System Vidard with closed imperial...	1867	80	4.800	7,500	1,560
Luggage vans.	*Southern* : Frame in wood.	1872	Tons 5	5,000	6,400	1,300
	Western : Frame in wood.	1870	5	5,000	6,800	1,400
	Orléans : Side pieces in iron................	1874	6	6,000	7,300	1,200
	Paris-Lyon-Méditerranée : Frame in iron........	1874	4	4,000	7,400	1,850
	Northern : Side pieces in iron (6 wheels)........	1874	6	6,000	9.000	1,800
	§ II. Goods wagons.					
Covered wagons.	*Eastern* : Side pieces in iron (body 4m,80)....	1866	10	10,000	4,400	440
	Orléans : Side pieces in iron................	1873	8	8,000	6,000	750
	Northern : Side pieces in iron................	1870	10	10,000	6,400	640
	Paris-Lyon-Méditerranée : Frame in iron........	1874	8	8,000	7,000	870
Coal wagons.	*Western* : Frame in wood.	1872	10	10,000	4,300	430
	Orléans : Side pieces in iron................	1873	10	10,000	4,500	450
	Northern : Side pieces in iron..............	1872	10	10,000	5,000	500
	Paris-Lyon-Méditerranée : Frame in iron........	1874	10	10,000	5,300	530
Trucks.	*Southern* : Frame in wood.	1874	10	10,000	4,300	430
	Northern : Side pieces in iron................	1870	10	10.000	4,400	440
	Charentes : Side pieces in iron................	1870	10	10,000	5,000	500
	Paris-Lyon-Méditerranée : Frame in iron........	1873	10	10,000	5,800	580

THIRD SECTION.

INTERNAL NAVIGATION,

RIVERS AND CANALS.

XVI

NAVIGATION BETWEEN PARIS AND AUXERRE.

SUBSTITUTION OF CONTINUOUS NAVIGATION FOR THE INTERMITTENT SYSTEM OF «ÉCLUSÉES»[1] ON THE YONNE.

Drawings on scales varying from 0^{m},000 025 to 0^{m},5.

The water communication between Auxerre and Paris follows the line of the Yonne between Auxerre and Montereau, for a distance of and that of the Seine between Montereau and Paris, for a distance of:

the Yonne between Auxerre and Montereau, for a distance of..............	$119,586^{m}$
and that of the Seine between Montereau and Paris, for a distance of...............	98,000
Total length...........	$217,586^{m}$

The navigation between Auxerre and Paris was intermittent for more than three centuries, and during 8 or

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[1] «Éclusées» on the river Yonne, are temporary and factitious risings of water, created by the regular and successive closing and opening of the navigable passages and barrages established along its course, and these bodies of water carry the various boats, rafts, etc.

9 months in the year, from March to November, was carried on by means of éclusées of the upper Yonne (1).

The continuous system of navigation, procuring a minimum depth of water of $1^m,60$, has been in operation since the month of September 1871, between Paris and Laroche, and since the month of September 1874, as far as Auxerre. This result has been brought about by the establishment of 12 movable barrages with locks, on the Seine, and 25 movable barrages on the Yonne. Twenty two of these latter are provided with locks, and three come under the head of derivations or cuttings.

THE RIVER YONNE.

The course of the river Yonne between Auxerre and Montereau (represented by a general plan and a longitudinal section), is divided into two parts. The first part between Auxerre and Laroche, 27,616 metres in length, is from 60 to 80 metres in breadth, with an average slope of $0^m,000\,667$ per metre, and a discharge of 13 cubic metres at low water mark; when the river is high, the discharge varies from 300 to 500 cubic metres. The second part from Laroche to Montereau, 91,976 metres in length, has a breadth of bed from 80 to 100 metres, an average slope of $0^m,000\,349$ per metre, and a discharge of 17 cubic metres at low water mark; during great risings the discharge varies from 700 to 1,100 cubic metres.

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(1) From the previous note it will be seen that the word «éclusée» has no equivalent in English. Though the word «écluse» signified *a lock*, in the present instance there are no locks in question. (*Translator.*).

Of the 25 locks on the Yonne, 22 have a breadth of invert of $10^{m},50$ and a working length of 96 metres; they are thus able to receive 6 canal boats or two rafts of wood, coupled.

The three other locks, which are old, have a breadth of $8^{m},30$; two of these, viz Epineau and Port-Renard, have a working length of 181 metres, and can also receive 6 canal boats or two wood rafts. The third, that of Chaînette at Auxerre, has a working length of 93 metres; and can receive 3 boats or one raft.

All the gates of the locks are of wood, and each gate is worked by a circular rack and pinion with a winch.

Between Auxerre and Montereau, there are twenty five movable barrages and three derivations.

Three of the twenty five are old, and on the system Poirée, that is to say, they have a permanent or fixed weir, in masonry, and a passage closed by trestles and paddles (1). These are the barrages of Chaînette, Épineau, and Port-Renard. The twenty two new barrages have a passage closed by movable shutters (Chanoine's system), worked by a bar furnished with cams, and by the aid of a boat. In thirteen barrages between Laroche and Montereau, the weir is surmounted by movable shutters and worked by the aid of a foot-bridge, and in six, between Auxerre and Laroche, the weir is surmounted by trestles and paddles, with a foot-bridge at least 25 centimetres above the head water level. This foot-bridge has not been raised to the usual height, owing to an apprehension, that the paddles might be difficult to work. One barrage only, that of l'Île-Brûlée, near Auxerre, is fitted with large shutters (Girard's system).

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(1) These are sometimes called *needles*. (*Translator*.)

The sill of the passage is generally placed 50 or 60 centimetres below low water mark; but the capping of the weirs of the three barrages, on Poirée's system, is level with the head water; the sill of the other weirs is 50 centimetres below low water mark.

In order to avoid abrupt bends in the river, three derivations or cuttings have been made, viz.

That of Gurgy, with a length of 5,007 metres.

That of Joigny, with a length of 3,574 metres.

That of Courlon, with a length of 4,134 metres.

These three derivations shorten the distance from Montereau to Auxerre by 11,309 metres.

At the head of each derivation, there is a stop-gate to keep out the flood water.

The breadth at the bottom of each derivation is 16 metres, and the depth below the normal level of the water, $1^m,80$, with a talus of 3 metres of base for 2 metres of height, which gives a breadth of $21^m,40$ at the surface of the water. The banks or towing paths, are from 4 to 6 metres in breadth, and are elevated at least 50 centimetres above the highest inundations known. The passage under the bridges is reduced to $10^m,50$, and the height of the intrados above the level of the water, is $5^m,50$.

THE RIVER SEINE.

Between Montereau and Moret, for 12 kilometres, the Seine has a breadth of bed 100 to 110 metres, an average slope of $0^m,000218$ per metre, and a discharge of

28 cubic metres at low water mark. Between Moret and Paris the breadth of the river is from 140 to 170 metres, the average slope 0^{m},000195 per metre, and the discharge at low water, 32 cubic metres below Loing, and 52 cubic metres below the Marne, at the entrance of Paris. The discharge, when the river is very high, varies from 900 to 2,000 cubic metres per second, between Montereau and Paris.

Below Montereau, the height at low water mark is 0^{m},50 to 0^{m},60. The risings commence at a height of 2^{m},50; the navigation up the river is stopped at 3 metres, and the down navigation at about 3^{m},50. The most considerable risings attain a height of 4^{m},90 at Montereau, 5^{m},80 at Melun, 6^{m},35 at Corbeil and 7^{m},50 at Paris.

The navigable condition of the Seine between Montereau and Paris, previous to the month of September 1871, was powerfully influenced by the system of «éclusées» on the Yonne; so that for nearly three quarters of the year the navigation was intermittent. This precarious and inconvenient state of things on a river, of such importance as the Seine, has ceased to exist since the month of September 1871, owing to the construction of twelve barrages during the last few years, between Montereau and Paris.

These twelve barrages had been constructed according to Chanoine's system, that is to say, with movable shutters 1^{m},20 in breadth for the passage, and shutters, called self-acting, 1^{m},30 in breadth for the weir; the space between the shutters when raised, was 0^{m},10. The barrage at Melun has alone, retained for the weir, the trestle and paddle system in use on the right branch of the Seine.

Experience has led to the detection of some faults in the working of the original shutters, and a movable foot-bridge on trestles, and with a plank flooring, has been constructed on the upper or head side of the shutter-weir. From this bridge the shutters can be worked with facility and security, by means of chains and a travelling winch. (See model.)

The navigable passages in masonry, are from 40^{m},40 to 65^{m},10 in breadth; the sill is in wood, solidly embedded in a platform 10 metres in breadth, and is 3 metres below the level of the head water, and 0^{m},60 below low water mark. The new weirs are 60^{m},30 to 70^{m},10 in length, and the sill is 0^{m},50 above low water mark; the platform, 4 metres in breadth, is formed by a wooden enclosure filled in with beton and surmounted by cross-beams, also in wood, between which is a paving in stonework. Each weir is comprised between a pier 3 metres in thickness, which separates it from the passage, and a spur, connecting it with the bank.

The locks have a chamber 12 metres in breadth with a working length of 180 metres(1), so as to receive 12 canal boats or four rafts of wood.

The lower sill of the lock is placed at least 1^{m},60 below the head water of the lower barrage, this head water being supposed to be horizontal.

The cappings of the barrages and locks are at least 0^{m},40 above the upper water level.

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(1) These exceptional dimensions appeared necessary on account of the great number of craft of all descriptions and tonnage which arrive from the Yonne, the Petite-Seine and the ports of the Seine between Montereau and Paris.

TELEGRAFIC COMMUNICATION.

A line of telegraph has been established between Paris and Auxerre, and already renders important service by placing each barrage in communication with those above and below.

COST.

1. On the Yonne between Auxerre and Montereau.
(Length of river made navigable, 108,277 metres.)

Seven barrages with locks from Auxerre to Laroche.	2,219,000^{f},00
Barrage of Gurgy without lock.................	140,000 ,00
Eight barrages with locks from Laroche to Sens....	3,696,000 ,00
Barrage of Joigny without lock.................	170,000 ,00
Seven barrages with locks from Sens to Montereau.	3,927,000 ,00
Barrage of Courlon without lock...............	200,000 ,00
	10,352,000^{f},00
12,715 metres of derivation, large section........	3,031,891 ,75
Various works, dredging, embankments, improvement of towing paths, plans, etc.............	3,440,188 ,51
Total cost between Auxerre and Montereau (1).	16,824,080^{f},26

2. On the Seine, between Montereau and Paris.
(Length of river made navigable, 98,000 metres.)

Five barrages with locks from Montereau to Melun.	4,046,416^{f},25
Six barrages with locks from Melun to Ablon:.....	5,185,411 ,20
Barrage with lock at Port-à-l'Anglais............	1,580,732 ,36
Various works, dredging, embankments, improvement of towing paths, plans, etc.............	3,541,500 ,19
Total cost between Montereau and Paris.....	14,354,060^{f},00

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(1) The interest of the cost of the first establishment, augmented by the annual expenses of management, represents, for the average traffic, nearly 2 centimes per ton and per kilometre for the Yonne, and 1 centime for the Seine.

The authors of the plans and the engineers that directed the works, relating to the establishment of continuous navigation between Paris and Auxerre, are:

For the Seine, MM. Chanoine and Cambuzat, engineers in chief «des Ponts et Chaussées»; MM. de Lagrené, Garceau, Boulé, Lévy (Maurice) and Lévy (Théodore), resident engineers.

For the Yonne, M. Cambuzat, engineer in chief, and MM. Pille, Marini, Humblot, de Dartein, Remise, Lévy (Théodore) and Chigot, resident engineers.

XVII

MOVABLE SHUTTER WEIRS

ON THE UPPER SEINE

ABOVE PARIS.

Drawings on scales varying from $0^m,000\,025$ to $0^m,5$.
Three models on a scale of $0^m,10$.

The barrages of the upper Seine consist of two parts: a navigable passage from 40 to 55 metres, and a weir from 60 to 70 metres in breadth, provided with movable shutters. The two parts are separated by a pier, and a lock is generally joined to the barrage.

The sill of the navigable passage is placed $0^m,60$ below low water mark. The shutters are 3 metres in height and are level with the water, which gives $2^m,40$ for the depth of the upper or head water above low water mark.

The floor or platform is in beton and is 2 metres in thickness, without the paving; its breadth is 6 metres for the portion intended to receive the various parts of the movable barrage, but the total breadth in the sheet piling enclosure, is about 10 metres. To resist the strain caused either by the pressure of the shutters or by any possible under pressure, the flooring has been strongly secured by iron bars anchored in the beton, also by vertical, transverse, and longitudinal bolts. A wooden sill or ledge

$0^m,45$ in thickness extends the whole length of the flooring, to which it is fastened by the series of disc anchors, and its upper face serves for a support to the base of the shutters, while the lower part carries the sockets of the chevalets.

A shutter consists of a wooden frame, $1^m,20$ in breadth by $3^m,11$ in height, bearing $0^m,08$ on the sill; and of a wrought iron chevalet and counterfort. An intervening space of $0^m,05$ to $0^m,15$ is left, according to the discharge of the river at low water mark.

The frame work of a shutter is composed of four uprights, two end tie pieces, a cross bar and thick planking; iron cramps and knees bind the different pieces together; and the uprights are $0^m,14$ by $0^m,13$ square, but diminish in size towards the upper end. To the intermediate uprights are bolted two collars, which receive the two gudgeons of the head of the chevalet, and constitute the axis of rotation of the shutter. Not being a self-acting shutter, this axis is placed above the third, or at nearly five twelfths of its height. Each of these gudgeons has a stop or catch, which limits the turning of the shutter to an inclination of 15 degrees, in order to avoid too great a strain on the breech in lowering. A counter-poise of about 66 kilogrammes, is attached near the bottom of the shutter, to balance the weight of the upper part when the breech is submerged. The chevalet is a trapezium, strengthened by a cross bar, and is $1^m,47$ in height, $0^m,76$ in breadth at the base and $0^m,45$ at the top; the irons are $0^m,065$ by $0^m,035$. The bottom terminates in two gudgeons received by sockets let into the sill, on which the chevalet can turn, for the purpose of being lowered upon the floor, with the shutter it supports. The upper cross-piece is also fitted with two gudgeons, constituting the axis of rotation of the shutter. In short, this same cross-piece forms one with the two projecting vertical cheeks, between which, the head of the counterfort or support is placed, the head and cheeks being joined by a bolt $0^{m},05$ in diameter.

The counterfort is a wrought iron bar, $2^{m},70$ in length by $0^{m},09$ in diameter, and is intended to support the shutter and the weight of the head water. It is jointed at the top of the chevalet by a bolt, and the lower end abuts against a cast iron shoe or catch, strongly embedded in the flooring. This shoe, in the form of an inclined plane, $0^{m},35$ in length and $0^{m},10$ in height, is inserted into two widened ears, projecting $0^{m},06$, and has a guide bar, much bent, $1^{m},52$ in length, terminated by an ear, also projecting $0^{m},06$. When it is desired to lower the shutter, the end of the counterfort is removed, and as soon as it leaves the front of the shoe, it slides along the guide bar, while the chevalet, turning on its base, falls with the shutter upon the flooring. To raise it, the base is furnished with a broad iron handle, with which the keeper connects a hook attached to a rope. Then, by means of a small winch fixed in a boat for this purpose, the various parts are successively raised; the breech, the chevalet, and lastly the counterfort, the foot of which moves up the inclined plane and resumes its place against the shoe. The fall of water assists this operation to a considerable extent, since it tends to raise the frame of the shutter, of which the axis of rotation is placed at a certain height above the sill.

The feet of the counterforts are disengaged from the front of the shoes by means of a bar with projecting cams, guided by pins, and working on rollers. It is terminated by a rack and wheel, geared to a crab winch fixed in the pier. When the breadth of the passage exceeds 30 metres, two bars are used, placed end to end, and worked in opposite directions from each extremity of the weir. The cams are placed at such a distance from each other, that the range of one bar shall be less than the space between two counterforts. For this purpose, they are arranged so as to lower the first shutters one by one, the next, two by two, the last, three by three.

The operation of opening a passage, is performed from the bank, and by the aid of the winch, in 3 seconds per metre run; the closing is effected with a boat at the rate of 1 minute and a quarter.

The average cost, per metre run, of these barrages with movable shutters, amounts to 3,070 francs, of which sum 2,278 francs are for the fixed, and 792 for the movable part.

The weirs of the upper Seine are from 60 to 70 metres in length. They are levelled to $0^{m},50$ above low water mark, and are formed of beton run into an enclosure of piling and covered with a paving in millstone grit $0^{m},30$ in thickness. The breadth of this solid part is 4 metres, allowing a range of 1 metre, above and below, for the shutters when lowered. A possible subsidence of the beton under the movable parts, has been obviated by the employment of cross-pieces and longitudinal beams, laid on the two lines of piles composing the enclosure, and by a third row of intermediate piles driven home.

The self-acting shutters of the weirs, are 2 metres in height by 1^{m},30 in breadth, and are formed, like those of the passages, according to the original system conceived by M. Chanoine, engineer in chief, i. e. to rise and fall of themselves.

Owing to the position of the axis of rotation, these shutters raise and lower themselves, this axis being only raised 0^{m},05 above the third of their height; there is also a movable counterpoise.

The striking simplicity of this ingenious system of shutters, called self-acting, led to some isolated experiments being made in a single barrage. But the working of the system being more completely tested by its application to twelve weirs on the Seine, between Montereau and Paris, some grave miscalculations were made apparent. The self-acting shutters lowered themselves too quickly, and did not rise till after a lowering of 1 metre of the upper or head water. A foot-bridge was constructed above each weir.

This was composed of iron trestles, after the Poirée system of barrages, movable on a horizontal axis perpendicular to the axis of the weir. Each trestle corresponds to the axis of a shutter. The tops of the trestles are connected by two bars, which limit the breadth of the foot-bridge, and between these bars a planking is laid, 0^{m},50 above the level of the head water. The two bars form rails, along which runs a truck carrying a winch with two chains, one of which is attached to the head, the other to the breech of a shutter. By means of the winch, firmly secured to one or two of the trestles, the necessary manœuvres are accomplished without fatigue or danger. During a flood, the trestles of the foot-bridge are lowered into a frame, nearly level with the platform, while the planks, bars and winch are stowed away. The counterpoises, being no longer useful, have been removed.

The new system has been a complete success. At night, every keeper is warned of any variations in the upper water of the barrage, by the ringing of a bell put in motion by a float. In addition, all the barrages communicate with each other by telegraph, and the excellence of the arrangements precludes the possibility of surprise.

NEW NAVIGABLE PASSAGE OF THE PORT-À-L'ANGLAIS BARRAGE.

In consequence of fresh arrangements for establishing an uninterrupted passage by the Seine to Paris, it became imperative to lower, by 1 metre, the tail-sill of the lock at Port-à-l'Anglais. This circumstance necessitated the construction, on the left side of the weir, of a new navigable passage $28^{m},70$ between the abutments, thus reducing the breadth of the weir to $37^{m},90$; the former passage $54^{m},70$ being maintained in its primitive state. The passage is closed by twenty six movable shutters, after the system of M. Chanoine, the sill being 70 centimetres below that of the old passage, which is closed by shutters of 3 metres; the new ones are therefore $3^{m},70$ above their sill.

To sustain the pressure of so considerable a body of water, it was necessary to effect some alterations in the models originally adopted by M. Chanoine for the movable shutter barrages. (See model.)

1. The breadth of each shutter was reduced to 1 metre instead of 1^{m},20; the intervening space of 10 centimetres between two shutters was retained, and the frame work was simplified. It consists of two uprights joined by four cross-pieces; these uprights are 3^{m},86 in length and 30 by 20 centimetres square, and the planking is 5 centimetres in thickness.

2. The inclination of the shutters from the perpendicular (8 degrees in M. Chanoine's model), was increased to 20 degrees, in order to diminish the strain tending to tear up the sill of the platform.

3. When a shutter is lowered, it bears on four rests, making one with the platform; in addition, the shutter is raised by two cleats fixed to the uprights, and by this arrangement, the shutter is perfectly supported and no dislocation of the frame is to be feared.

4. In M. Chanoine's original model, the axis of rotation was placed at 5/12 of the total height, and for the new shutters at Port-à-l'Anglais, this plan would give to the breech a height of nearly 1^{m},60; 1^{m},75 has been adopted, and the axis of rotation placed only 15 centimetres below the axis of figure.

This method prevents them from turning spontaneously, an inconvenience that the former shutters sometimes presented when the tail water was too high, and the fall of the barrage unusually small. This objection is in course of removal, by contriving small self-acting valves in the fly or upper part of the shutter between the uprights, 1 metre in height by 42 centimetres in breadth, and moving on a horizontal axis. These butterfly valves open spontaneously before the shutter comes to the balance, and the keeper can close them with the greatest facility, by means of a gaff, from a boat behind the barrage.

5. For raising the large shutters of the new passage a foot-bridge has been substituted for the use of a boat. It consists of trestles (Poirée's system), on which travels a winch.

The trestles of the foot-bridge are $4^m,75$ in total height, $3^m,10$ in breadth at the base and $1^m,20$ at the top. A trestle is in the perpendicular of the axis of each shutter, and the planking of the bridge is 50 centimetres above the normal level of the head water of the barrage. The uprights above and below, the diagonal stays and cross-braces are in U iron 8 centimetres in breadth, 35 millimetres in depth and 7 millimetres in thickness. The lower cross-bar is 8 centimetres in diameter. All these pieces are joined together by broad iron corner plates 7 millimetres in thickness.

M. Chanoine, engineer in chief « des Ponts et Chaussées », and M. de Lagrené, resident engineer, drew up the plans and directed the works of the original lock barrage at Port-à-l'Anglais; M. Cambuzat, engineer in chief, and M. Boulé, resident engineer, drew up the plans and directed the works of transformation of this barrage.

MM. the conducteurs Roger-Queux, Nicolle, Bertauche and Ponteau, superintended these last works, which were executed by the contractors Bathier, Canapville, Denuelle and Marc, and by the firm of Claparède, of Saint-Denis.

XVIII

WEIR OF THE BARRAGE OF L'ÎLE-BRÛLÉE,

ON YONNE.

M. GIRARD'S SYSTEM OF SLUICES AND HYDRAULIC PRESSES.

Drawings on scales varying from $0^{m},000\,025$ to $0^{m},5$.
Model on a scale of $0^{m},10$.

The weir of l'Île-Brûlée is surmounted by large sluices invented by M. Girard, civil engineer. This system comprises (1):

1. A series of wooden sluices, movable round a horizontal axis, and capable of turning inside a cast iron cylinder or case let into the top of a stone flooring.

2. Hydraulic presses fixed on the lower slope of the platform, solidly anchored in the masonry and intended to work each sluice. The piston-rod of each of these presses carries a cross-beam guided by slide bars, by which it is supported, and to this cross-beam are fitted three connecting-rods jointed to another cross-beam attached to the middle of the movable sluices.

3. A series of copper tubes, which put each press in communication with the generators and reservoirs of

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(1) *See* model.

force, destined to convey the water under pressure to the hydraulic presses.

4. An hydraulic machine constructed on the abutment of the barrage. This machine consists of a turbine with vertical axis, a double action pump worked by the turbine, and a generator. The pumps and generator communicate with each other and with the presses, by the medium of three way cocks, which allow the water to be forced back either into the generator, or into the presses, or to be discharged into a waste-pipe.

The working of the sluices is performed by the simple action of these cocks. By putting each press in communication, either with the pumps, or with the reservoir under sufficient pressure, an upward movement of the piston is produced, and the sluice rises. On the other hand, by opening the discharge cock, the water escapes under the pressure of the sluice valve, the body of the pump is emptied, and the sluice is lowered.

The reservoir of force regulates the action of the pumps, it also allows the sluices to be raised when there is not sufficient fall to work the turbine.

The weir of l'Île-Brûlée is 25 metres in length; the sill is levelled to 2 metres below the level of the head water, and the fall is $1^{m},85$.

The sluice valves are seven in number, and are $3^{m},52$ in breadth by $1^{m},97$ in height. When raised, they present an obstruction of $0^{m},40$; when lowered, they rest horizontally upon the platform or floor.

The presses are also seven in number; they are in cast iron with an exterior diameter of $0^{m},40$ and a thickness of $0^{m},04$. The piston is in cast iron with a bronze casing; the diameter is $0^{m},30$, and it works in a packing of hot pressed leather, which constitutes a joint the more water-tight as the pressure becomes stronger.

The supply pipes lead into the body of the presses; their diameter is $0^{m},025$, and there is one for each press. They are let into the thickness of the platform, and terminate in distribution cocks in the interior of the hydraulic machine.

In order that the presses might be sheltered from frost, they were established entirely below the down stream level; but this arrangement presenting considerable difficulties in the way of inspection and repair, stone walls were contrived between each press, by the aid of which, small plank partitions can be formed, and each compartment pumped out for the purpose of inspection or repair.

The turbine has a diameter of $1^{m},20$, and moves directly, by its upper crank, a double action water pump and an air pump, which drive back the water and air into the generator, under a pressure capable of being raised to 25 or 30 atmospheres.

The reservoir is a cast iron cylinder $0^{m},66$ in interior diameter, $3^{m},50$ in height, and $0^{m},05$ in thickness. This reservoir and all the machinery have been tested under a pressure of 35 atmospheres.

The dimensions of the various parts of the weir were calculated by M. Girard, in order that the pressure might never exceed 25 atmospheres. This pressure is necessary to raise the shutters against the a complete fall of $1^{m},85$. The machinery works with remarkable rapidity and regularity, and a large sluice valve can be opened in less than a minute. Eventually, it will be practicable to diminish the pressure necessary to raise the water, by fitting the large sluices with small butterfly valves, and the experiment has been made upon two of them. These valves, three in number for each sluice, are placed in the upper part, and have their axis of rotation at a third of their height. When the sluice is lowered, they incline in the direction of the stream which covers them, and being in thin sheet iron, offer no resistance to the pressure of the water, so that the strain upon the sluice at starting, is considerably reduced. When the sluice emerges from the water, the butterfly valves close themselves.

When the sluices are raised, a pressure of 7 or 8 atmospheres is sufficient to sustain them; and it is not necessary to leave the presses in communication with the reservoir. It is only necessary to close the distribution cocks, and the presses, being all perfectly tight, remain as before, and do not empty themselves.

The cost of construction of this system of barrage, is 2,000 francs per metre run, and 3,000 francs with the stone-work.

The trestle and paddle weir costs only 1,200 francs per metre run, everything included, in this part of the Yonne, where the foundation work is not difficult. The hydraulic press system, notwithstanding its superiority in convenience of working, has the disadvantage of being very costly.

M. Cambuzat, engineer in chief, and M. Remisse, resident engineer, drew the plans and directed the works of the lock-weir of l'Île-Brûlée; M. Callon, constructor, and the firm of Feray, d'Essonnes, executed the weir sluices on Girard's system.

Particular mention should be made of M. Girard, the inventor, whom a premature death has carried off from a course of patient study and ingenious research.

XIX

MOVABLE WICKET WEIRS OF THE BARRAGES ON THE MARNE.

DESFONTAINES SYSTEM.

Between 1855 and 1867, fourteen barrages were constructed to improve the navigation of the lower Marne, between Épernay and Charenton (Seine), a distance of 178 kilometres. Of this number, eleven comprise a weir fitted with movable wickets, in addition to a lock and navigable passage. The excellence of this system has now been completely tested by the experience of eighteen years, and was invented by the late M. Desfontaines, chief engineer of the navigation of the Marne, afterwards nominated inspector general des Ponts et Chaussées, and who died in 1867. The system will be comprehended without difficulty, by inspecting the model sent to the Exhibition at Philadelphia.

Solid part of the weir. — The difference of water level at these dams is usually about 2 metres; that of Joinville, the last constructed, is $2^m,16$. The stone weir rises to half the height included between the upper part or head, and the lower or tail, consequently the movable shutters are 1 metre in height ($1^m,10$ at Joinville).

In the two barrages first built, the solid part was in dry rubble, but for the others, mortar was used, as a precautionary measure against possible filtration. The one in question is comprised between two rows of piling, bound by horizontal wales. When dry rubble was employed, sheet-piling was added to the upper row, forming a perfectly water-tight screen. Subsequently ordinary sheet-piling was added to the lower row, thus constituting an enclosure in which to run the beton.

General idea of the drum-shutters. — Let the reader imagine an iron plate sluice or valve, 2 metres in height by 1m,50 in breadth, movable round a horizontal fixed axis, and capable of describing a quadrant. If the axis is placed at the top of the fixed weir, the upper part of the valve will form a movable wicket, while the lower part or counter-wicket, cannot act unless a proper space or cavity is prepared for it; a species of drum, the axis of which is horizontal. The transverse section of this drum, parallel to the axis of the river, consists of a quadrant, joined on the lower or tail side, by a rectangle.

The wicket is moved by the counter-wicket, and the motive power is the pressure resulting from the difference between the upper and lower water-levels, or in other words, the head and tail of the barrage. It is therefore a question of the effective application of this power to the counter-wicket.

If the drum is closed at the ends by two vertical plates, and covered on a level with the axis of rotation by a horizontal plate, a closed box will be formed, divided into two compartments by the counter-wicket, two sectors, of which the dimensions vary according to the position of the counter-wicket, and there is an upper or head, and a lower or tail compartment. When it turns, the counter-wicket nearly touches, or within 3 or 4 millimetres, the cylinder and the vertical ends of the drum. But when, with the wicket, it is in a vertical position, a ledge or projection completely stops its progress, and by the aid of an India rubber band, the surface of contact is rendered perfectly water-tight.

This counter-wicket does not however prolong the wicket; it is bent from the hinge and only resumes a position parallel to the wicket at a distance of $0^m,30$ or $0^m,40$. It follows from this, that the wicket being in a horizontal position, the counter-wicket though also horizontal, leaves a space of $0^m,40$ between it and the cylinder. Now by putting this space, this head compartment, in communication with the head or upper water level, while the tail compartment, more or less empty, is put in communication with the lower or tail water; the counter-wicket may descend, notwithstanding the static and dynamic pressure which tends to retain the wicket in a horizontal position. The power acting upon the counter-wicket must consequently preponderate, inasmuch as the counter-wicket presents a larger surface and is placed lower, therefore the wicket will now rise.

The wicket can be lowered by leaving it to itself, and intercepting the communication between the upper or head water, and the upper compartment in the drum. But the Desfontaines apparatus has a double action; for the lower compartment of the drum can be put in communication with the upper water level, while the upper compartment can be made to communicate with the lower or tail level. Then the back pressure upon the counter-wicket, causes it to rise, and so much the more easily, that the current always tends to lower the wicket.

Passing from abstractions, to arrive at a veritable barrage of any length, three hypotheses present themselves for realisation, three problems await solution :

1. To create, at discretion, a communication between the head compartment of the drum and the head water, while the tail compartment communicates with the tail water, and *vice versa;*

2. That the action should not be limited to a single drum 1^{m},50 in length, but extend to an indefinite number of similar drums, arranged side by side and in absolute contact;

3. To establish a sufficient original fall.

Let the reader imagine two culverts contrived in the abutment barrage, parallel to the axis of the stream. Both are fitted with a valve at each end, and connected by a transverse conduit; the one with the upper or head compartment of the drum, the other with the lower or tail compartment. It is clear that by proper management of the four valves, the problem admits of solution. But the perspicuous intelligence of M. Desfontaines immediately discerned the possibility of the three following conditions :

1. The reduction of the two culverts to one, with a rectangular opening 1^{m},20 by 0^{m},80, divided into two by a horizontal cast iron plate 0^{m},03 in thickness;

2. The expediency of employing two valves in lieu of four, each of the two to close one outlet simultaneously with opening the other;

3. The substitution of a single movement, in working

the valves; this movement to be transmitted from the upper to the lower end of the culverts by a balance beam similar to that of a steam-engine.

Passing to the second point.

It was necessary to make two openings in one of the ends of the drum, corresponding respectively with the two transverse conduits, so that the water leaving the culverts may enter the drum or leave it. Similar openings formed in the other end of the drum, or in the plate separating two consecutive drums, will permit the passage of the water from one to another, and act successively upon each of the counter-wickets. If the water were to act upon several counter-wickets at the same time, the loss or leakage by the three free edges of the counter-wicket would perhaps prevent its arrival in sufficient quantity, but it only passes into a second drum after having filled the first, and this operation successively transforms the drums into so many closed vessels. No point in the system has been less remarked, or more imperfectly comprehended than this, which is, however, the one which most exercised the ingenuity of M. Desfontaines.

Further on, the practicability of originating the small lift, will be treated.

Drums in iron or stone-work. — Drums formed entirely of iron were employed in the two barrages first constructed by M. Desfontaines. They presented, on the head and tail sides, horizontal flanges, which were bolted to the wales of the two rows of piling. For the other drums, he considered stone-work preferable, and in the whole length of the weir a cavity of convenient section was formed, admitting of subsequent division into lengths of $1^{m},50$, by means of cast iron diaphragms let $0^{m},08$ into the masonry.

A cast iron tube, carrying the wrought iron spindle and the wicket, is supported at the ends by two consecutive diaphragms. In the head part, the cavity is covered (in the barrage last constructed), by an iron plate which can be opened, thus permitting the drums to be examined, while below, the cavity is covered by a cast iron plate fastened by bolts.

On the barrage of Joinville, a small travelling crane raises successively each of the spindles with its wickets, for the purpose of repainting them with coal-tar, while the head water, which has never fallen since 1867, is retained by a coffer-dam consisting of superposed beams, supported in a horizontal position by small Poirée trestles.

Partial lowering of the wickets. — The variation in the volume of water discharged by the river, renders it necessary, during a part of the year, to modify the overfall of the weir. To meet this exigency, M. Desfontaines had fitted to the tail-face of the wickets (at four of his barrages), a jointed crutch, of which the foot, sliding on the top of the weir, could be stopped by a catch or sill of angle-iron, and mechanically brought to the proper place. The wicket, inclined at an angle of 45°, for instance, is then sustained by the crutch, in the same manner as the swinging shutters of navigable passages are kept in position by a prop. Although this idea is taken from another system, there remains still one important difference, viz. that with the Desfontaines wickets, it is not necessary to trip or unfix the props laterally, and by main strength, when they are subjected to a heavy pressure of water. When it is necessary to lower them entirely, they are first raised to the perpendicular, and the stops or catches, which have been temporarily used, are removed.

There are no crutches in the barrage last constructed. The shutters are always, with the exception of two or three, entirely up or entirely down; but they can be raised or lowered at pleasure. For this purpose, the water being always let into the culverts from one extremity of the weir, — at the pier for instance, — the abutment valve must be worked in a contrary direction.

The regulation of the head water is effected as follows:

From the abutment, the keeper tranquilly watches a hydrometric scale and turns, in the required direction, a handle commanding the valve that admits the water into the drums. He can limit the operation to raising or lowering a single wicket. If the raising movement is continued, the wickets are successively raised, and form a line with mathematical precision, the intervening spaces being barely 10 millimetres, which might easily be reduced to five. In this way, half the wickets can be raised; and at Joinville, 21 out of 42. Should it become necessary to raise them all, both valves must be raised or lowered, according to circumstances, in order to overcome the resistance hitherto maintained. When the pier and abutment valves are worked simultaneously, the operation (it might be called phenomenon) is accomplished in two minutes, at Joinville along a distance of 63 metres; and no engineer could witness unmoved, the upward movement of the last wickets, as they drive back the surging mass of water that rushes to the gradually contracted outlet of the weir.

Original fall. — The operation of raising the wickets is only necessary at certain seasons, when the waters of the Marne, after a flood, are liable to fall below the normal level. At this juncture a small lift becomes requisite. In the Marne barrages, this is partly originated by the reduction of section produced by the solid part of the weir, which projects from the bed of the river. In addition, the first operation is to close the navigable passage.

Navigable passage. — Of eleven barrages, to which the Desfontaines system is applied, ten have the navigable passage closed by swinging shutters. The system strongly resembles that established on the upper Seine; but the shutters were never raised by the assistance of a boat. Contrary to the plan of M. Carro, M. Desfontaines immediately constructed, at the head of the passage, a footbridge supported by Poirée trestles.

On the other hand, M. Desfontaines had laid it down as a principle, that the width of navigable passages ought not to exceed the requirements of navigation. The expenses are thereby reduced, and the serious difficulties attending the care of these movable machines are lessened, since they are much more easily managed when the sill which supports them has a smaller depth of water. For this reason, an opening of 25 metres only has been given to the navigable passages of the Marne.

For the rest, in the barrage last constructed, trestles were employed in preference to swinging shutters. The Poirée and Desfontaines systems harmonise completely.

and a mutual advantage results from the employment of both, which renders them exceptionally beneficial to navigation. The head water is regulated by the wickets, and in the event of floods, the facility with which an additional out-fall or discharge can be created, affords ample time for the removal of the paddles (aiguilles) and trestles.

Historical. — At the present time, when the Desfontaines system is to be officially presented to the notice of American engineers, it may not be out of place to supplement the preceding notice by a few explanatory remarks concerning its origin and development.

This system appertains to a class of barrages, of which the prominent and common feature consists in the fact of the fall constituting the motive power. In Holland, from time immemorial, fan-gates have been employed to close the irrigation canals. The unequal breadth of this kind of gate, renders it susceptible to the power generated by a moderate lift. This method is still in use at the present day, and was represented by a model in the universal Exhibition at Vienna in 1873 (1).

Probably the idea passed from Holland to America, for about the year 1818, it was applied on the river Lehigh in Pennsylvania, not in the form of gates with vertical quoin-posts, but with horizontal axes. It was noticed in the work of M. Michel Chevalier, published in 1843, and advocated by M. Mary, the result of which was its trial in

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(1) See *Report on public works at the Vienna Exhibition*, by M. Kleitz, inspector general «des Ponts et Chaussées», and president of the International Jury for group XVIII, p. 103.

France, on the upper Marne, by MM. Desfontaines and Fleur Saint-Denis. Although the work could not have been in more skilful hands, the first expectations were not realised. But this attempt failed not to leave in the inventive mind of M. Desfontaines the germ of an idea, which, carefully considered and diligently elaborated, has produced the present system; and it is with some pride that we now return to the other side of the Atlantic, the *American* barrage perfected under French auspices.

The movable wicket weirs of the Marne were constructed under the supervision of M. Desfontaines, by MM. Carro, Philbert and Malézieux, resident engineers. (See *Annales des Ponts et Chaussées,* 1868, 2nd half-year.)

XX

MOVABLE TRESTLE BARRAGE AT MARTOT,

ON THE SEINE.

Model in wood and iron. — Scale $0^{m},10$ (one tenth).

The works of the Martot barrage consist of a lock, of which the chamber is 105 metres by 12 metres; a first barrage connecting the lock with Geoffroy island, a weir with self-acting shutters, between this island and the isle of Moine, and a second barrage, between the isle of Moine and the left bank.

This last, a part of which is represented by the model, is composed of three passages 51 metres in breadth, between two abutments and three piers, the former 6 metres, and the latter $4^{m},10$ in thickness by 8 metres in length.

The floor is laid between two rows of sheet-piling, 10 metres apart, and has an average thickness of $2^{m},50$. It is in beton, covered with rubble in cement mortar, and squared stone. The stone-work includes : 1. the sill, which bears the upper coussinets and the stop-plate; these stones, which are dovetailed, are $1^{m},50$ by $1^{m},10$ in height at the stop-plate; 2. the upper plat-band continuing the cavity in an inclined plane to support the paddles or needles, this part is 1 metre in length by $0^{m},80$ in height; 3. the lower or down stream coussinets; 4. the lower plat-band: these two parts are together, $2^{m},25$ in length and $0^{m},80$ in thickness. Between these two plat-bands the floor is in millstone grit covered with a layer of Portland cement, and both sides are in dressed millstone grit.

The various parts are strongly bound together by large iron bolts $0^{m},04$ in diameter, traversing at distances of 5 metres, the whole framing below the stone-work, and connecting the horizontal wales of the sheet-piling. Vertical bars are also let into the beton, at distances of $3^{m},30$, in the stones of the coussinets, and connected in the upper part by three transverse bars which join them at the same time with each other, and with the horizontal wales of the upper and lower ends of the sheet-piling enclosure. Lastly, these uprights are again connected parallel to the barrage by two other sets of iron bars, $3^{m},30$ apart, screwed to the tops of the uprights, and cramped to the coussinets.

The movable trestles, established according to the system of M. Poirée, are $1^{m},10$ apart, $3^{m},35$ in height, $2^{m},48$ at the base and $1^{m},40$ at the top. At their base they are formed of round bar iron $0^{m},06$ in diameter, the uprights and cross-piece are in T iron, $0^{m},06$ in web and the same in flange; the two horizontal braces are in wrought iron with a web of $0^{m},012$, and flanges $0^{m},06$; the diagonal brace, also in wrought iron, has a web $0^{m},025$ in thickness and $0^{m},06$ flange. The four angles of the trapezium are strengthened by wrought iron corner brackets or knees; the upper ones are jointed and fitted with vertical gudgeons, while the two lower, form part of the base. The weight of each trestle is 212 kilogrammes.

The upper step-bearings or sockets are cramped into the sill-stones, and secured by an eye-bolt, those below, are fastened to the stone-work by three screw nuts, screwed on to three strong gudgeons let into the floors.

The trestles are sustained and bound at the top by bars above and below the weir. The up-stream bars that support the paddles, are formed of two flat bars of iron $0^m,08$ by $0^m,04$, riveted to each other, and having at each end a hole fitting the trestle gudgeon. The down-stream bars are in round iron.

The service-bridge consists of three rows of planking, $0^m,90$ in breadth and $3^m,30$ in length upon three trestles, and is furnished beneath with flanges which clasp the T irons, to prevent slipping; the planks are also held by small claws.

The trestles have no system of escape for the water, the paddles, which are of pine, 4 metres in length by $0^m,08$ square, have to be placed or removed by hand, one after the other.

The cost of this barrage including earth-work, dredging, pumping, accessory works and direction, amounted to 708,000 francs, or 4,050 francs per metre run.

It was constructed between 1863 and 1866 under the direction of MM. Beaulieu, engineer in chief, and Saint-Yves, resident engineer « des Ponts et Chaussées ».

XXI

IMPROVEMENT OF THE SEINE MARITIME,

FROM ROUEN TO HAVRE.

A drawing comprising: two plans of the whole on a scale of $\frac{1}{60000}$
(1 metre for 60,000 metres).
A longitudinal section:
on a scale of $\frac{1}{50000}$ (1 metre for 50,000) for the lengths;
and a scale of $\frac{1}{100}$ (0,01 per metre) for the heights.

For the entire distance of 127 kilometres between Rouen and Havre, the navigation of the Seine is completely free. There is neither rock, nor bridge, nor obstacle of any kind, to obstruct the progress of vessels. With the exception of the passage of the Meules, between la Mailleraye and Caudebec, 62 kilometres from Rouen, the draught of water, at the weakest flood tides, exceeds 5 metres. And even in the Meules, during the year 1875, there were only twelve days when the anchorage was less than 5 metres.

In 1845, the average tonnage of 4,795 vessels entering Rouen with cargo, was 102 tons. In 1875, the number of vessels entering, was 1,440, carrying 416,833 tons of goods. The average tonnage thus attained to 289 tons per vessel.

In the same year 1875, two days after the first quarter of the moon, and consequently neap-tide, there entered Rouen, a steamer laden with 1,080 tons of oats, and drawing 5m,19 of water. On the 7th September, the very day of the first quarter, another steamer entered, laden with 1,050 tons of goods and drawing 5m,33.

In short, the premiums of insurance, which were formerly 1/2 per cent for the single journey of the Seine, are negociated to day at the same rate for Rouen as for -Havre.

These prosperous results are owing to the improvement of the Seine, by means of various works undertaken by the Government, since the year 1848, and which consist in narrowing the bed of the river, by embanking in stone parallel to the stream.

This system was applied for the first time at the crossing of Villequier, one of the most dangerous passages of the Seine. Two longitudinal embankments, 300 metres apart, and made flush a little above the average high water at spring tides, had the desired effect, and a depth of 6m,50 was created below this level, where formerly there was only 3m,50.

This success fully bearing out the expectations of the engineers, the embankments were continued, and, from 1849 to 1866, they were extended as far as the mouth of the Risle, 32 kilometres below Villequier. In addition to this, the southern embankment was established for 2 kilometres below the Risle. Above Villequier, embankments were formed for 11 kilometres of total development. This part of the work was executed in short lengths, from 1852 to 1875, so as to reach la Mailleraye, a small river port 60 kilometres below Rouen.

With respect to the interval between the embankments, it increases progressively after leaving la Vaquerie, where the width is still 300 metres as at Villequier. Before Quillebœuf it reaches 400 metres, and at Tancarville 500. From this point, as far as the Risle, the embankments are exactly parallel.

Between the Risle and the great depths of water in front of Havre, the Seine has regularly kept to the southern part of the bay since the winter of 1871-1872.

The sides of the navigable channel are clearly indicated by beacons, carefully kept in order. An official report of the soundings, drawn up every fortnight, keeps the pilots informed of the number of metres and centimetres necessary to be added to the indications of the semaphores of Havre and Honfleur. By this means they know, at any time of the day, the minimum depth of water throughout the whole length of the channel.

All the embankments have been constructed with blocks procured from the chalky hills bordering the Seine. They measure, on the average, 1/8 of a cubic metre, and are piled one upon the other. The facings, starting from the level of ebb-tide, and the cappings, are the only parts laid by hand. Generally speaking, the embankments are 2 metres in breadth at the top, and on the land side, the talus is inclined to 45°, while on the channel side the inclination varies, in proportion to the nature of the bottom and the violence of the currents of ebb and flow, so that at certain points, the base is 7 or 8 metres, for one metre in height.

These works are, for the most part, on the same level as those of Villequier. By way of experiment, some low embankments, levelled to 2 or 3 metres above the lowest water mark, have been formed; in the first instance, just below Tancarville, and recently, on the left bank of the river between la Mailleraye and Çaudebec. This last attempt appears more likely to succeed than the other, doubtless on account of the greater tranquillity of the water.

From the commencement of the works till the 31st December 1875, the cost of the first establishment and of heavy repairs, was 16,860,000 francs. This sum includes 220,000 francs for deepening the peaty bottom of the passage of the Meules, which was accomplished by means of dredging.

In order to complete the repairs, and secure the embankments against the attacks of the river and damage by frost, a further outlay of about 2,500,000 francs will be necessary, commencing from the 1st January 1876.

The passage of the Meules will also require to be deepened, so that at the lowest flood tides there may be 5m,30 of water. The expense on this head will reach 150,000 francs.

Finally, a sum of 4 millions of francs will be devoted to the following works, conformably to the act of the 14 December 1875. Reconstruction of the quays at Rouen; completion of the lighting of the Seine; straightening and clearing the defective passages of Croisset and Bardouville (4 and 25 kilometres below Rouen). This latter operation will be effected by dredging.

The total of these expenses, will amount, in round figures, to 21,500,000 francs.

In addition to the advantages derived from an increased depth of channel, the construction of embankments has caused the formation of about 8,400 hectares of alluvial land, of which, 6,350 hectares constitute, at the present time, meadows of excellent quality.

In proportion as these reclaimed lands become consolidated, they are transferred to the proprietors along the river side, conditionally upon payment to the State of indemnities fixed at half the value of the lands acquired. The total of these collections will probably amount to 5 millions of francs.

Of these works, the greater proportion was executed from 1848 to 1867, under the direction of MM. Doyat, Beaulieu, Emmery and du Boulet, engineers in chief, and Partiot and Godot, resident engineers. From 1869 to 1875, the service was directed by MM. Lemaître and Bellot, engineers in chief, and Alard, resident engineer.

XXII

CANAL BRIDGE ON THE ALBE.

Model in wood and sheet-iron
representing two bays, one abutment and two piers, scale $0^{m},04$
(one twenty-fifth).

This bridge was constructed for the passage of the canal from the coal-mines of la Sarre, across the river Albe. It is 45 metres in length between the abutments, and consists of three bays, the central one having a span of 17 metres and the others $12^{m},50$ each. The piers are $3^{m},50$ in height below the capping, and rest on socles of $0^{m},40$; their thickness is $1^{m},50$ at the top, $1^{m},90$ at the base, $2^{m},10$ at the socle, and $2^{m},40$ below. They are surmounted by pilasters, between which is the iron trough or water channel. The length of the piers is $12^{m},50$ at the summit, and between the external faces of the pilasters; below the capping, and including the starlings, 14 metres; $14^{m},40$ at the base and 15 metres below the socle.

The metallic superstructure is $47^{m},60$ in length, 11 metres in breadth between the parapets, $6^{m},80$ of which are for the water channel and $2^{m},10$ for each foot-way or towing path. The sheet-iron trough which forms the water-way is rectangular in section, except that the two lower angles are rounded off in a quadrant of $0^{m},70$ radius; it is $2^{m},55$ in height and $6^{m},80$ in breadth. The perpendicular sides are formed by two girders of double T section, extending the whole length of the work. The webs of these girders are $3^{m},05$ in height and $0^{m},01$ in thickness; the horizontal flanges, of the same thickness and $0^{m},40$ in breadth, are bound to it above and below by two sets of angle-irons. In the perpendicular of the piers, these plates are doubled for the length of $3^{m},80$, tripled for $2^{m},60$, and quadrupled for $1^{m},50$; they are also doubled for 6 metres and tripled for 1 metre, at the middle of the bay. The flanges project from the web $0^{m},14$ inside, and $0^{m},26$ outside the work. A series of vertical stiffeners strengthen each girder, and are fixed on the outer side at distances of $1^{m},40$, reduced to $0^{m},43$ in the perpendicular of the piers, and to $0^{m},70$ on the abutments; they are made of special iron, also in double T, $3^{m},05$ in height, of which the web comprises $0^{m},26$ and the arms $0^{m},15$, and fit to the horizontal flanges of the girders.

The bottom or floor is $0^{m},008$ in thickness, and bends up as it meets the girders, so as to adapt itself to the vertical side, and follows a quadrant with a radius of $0^{m},70$. It is supported by thirty five cross-beams and three rows of longitudinal girders. The horizontal cross-braces are $1^{m},40$ apart and $0^{m},50$ in height, except near the girders, where they curve in a quadrant, in order to assimilate to the shape of the lower angles of the trough, which gives to their junction with the girders and counterforts, a height of $1^{m},20$. They are in double T, with web of $0^{m},50$ in height and flanges of $0^{m},22$ in breadth; the lower flange is doubled for 4 metres and the web is joined to the flanges above and below by a double series of angle-irons. Finally, three rows of longitudinal girders also in double T iron $0^{m},18$ in height and $1^{m},70$ apart, from centre to centre, bind the upper parts of the cross-braces and extend even to their lower flanges, by trapezoidal iron plates.

The trough is $6^{m},80$ in breadth by $2^{m},55$ in height: and the depth of water is $1^{m},80$, i. e. $0^{m},75$ below the flange of the great girders. The sides are protected from contact with the boats by floating pine beams, suspended by small chains, and extending the whole length of the bridge. In addition, rope and cork fenders are interposed between the pieces of pine and the sides, in order to deaden the shocks. And lastly, a round iron rail is fixed to the inner edge of the upper flange of the great girders, and serves to keep the towing lines at a distance from the sharp angles which would otherwise cut them.

The towing paths are $2^{m},10$ in breadth, of which $1^{m},80$ is clear road, and they are corbelled out on each head. They are supported by large double T iron brackets, in form of a quadrant with a radius of $1^{m},80$, vertically continued $0^{m},40$ at its lower part. All the brackets are connected by a girder in double T, $0^{m},50$ and $0^{m},20$ in breadth, which supports the parapet and roadway; they are also braced horizontally by a series of diagonal stays in flat bar-iron $0^{m},08$ by $0^{m},01$, which alternately bind their ends by crossing the intermediate bracket.

Upon these brackets rests a series of double T joists, $1^{m},80$ in length by $0^{m},20$ in depth, that constitute the springing of some small brick arches of $1^{m},40$ span by $0^{m},14$ rise and $0^{m},11$ thickness, supporting a roadway in concrete, enclosed between two curb stones pierced with a certain number of holes to discharge the surplus rain water. The great girders of the water trough are $0^{m},25$ above the towing paths, and this prevents all contact between the iron-work and the legs of the horses.

The whole of the metallic superstructure is completely isolated from the stone-work, and rests on the points of support by means of expansion frames consisting of eight iron rollers $0^{m},12$ in diameter, the spindles of which are set in the same frame. These rollers are contained between a cast iron plate, securely embedded in each pier or abutment, and a second plate, grooved to receive the lower flange of the great girder. Each plate is itself composed of two parts, between which are four steel wedges that serve to regulate the position of the girders on each support.

The iron frame-work of the trough extends a little beyond the expansion frames of each abutment to a distance of $0^{m},50$ into the masonry, with which however it does not come into contact, there being a space between, of $0^{m},06$, which is filled with tarred oakum to render it perfectly water-tight. In this small space the section of the trough is perfectly rectangular.

The isolation of the water trough, for purposes of inspection and repair, is effected by vertical recesses in the stone-work of the abutment, in which a barrage of planks can be arranged together with a small culvert and discharge sluice.

The whole of the trough, except the brackets, was put together on the approaches of the bridge, and set in its place by means of cast iron rollers. By the aid of levers, fifty men performed this work in two days.

Under the permanent weight of water, and an excess weight of 200 kilogrammes per square metre, the maximum strain on the iron-work was 4 kilogrammes per square millimetre in the parts liable to deflection, and $4^{kg},50$ on those subject to pressure. Since letting in the water, it has been ascertained that the great girders deflected $0^{m},005$ in the central bay and $0^{m},003$ in the others; that the cross-beams deflected $0^{m},0025$, and that the sides of the trough bent inwards at the upper part, $0^{m},01$ from the perpendicular.

The total expense amounted to 148,000 fr., 98,000 of which (or 2,060 fr. per metre run) are for the iron-work, at the rate of 51 centimes per kilogramme of wrought and 35 centimes per kilogramme of cast iron.

The works were planned and executed from 1863 to 1866 by MM. **Bénard**, engineer in chief, and **Chigot**, resident engineer « des Ponts et Chaussées ».

FOURTH SECTION.

MARITIME WORKS,

SEA-PORTS.

XXIII

LOCK OF THE PORT OF DUNKERQUE.

Model in stone, wood, iron and bronze, representing the lock with gates and swing-bridge. Scale 0^{m},04 (one twenty-fifth).

This lock, 21 metres in breadth, was not provided with a chamber, for the reason that it has to give passage to ships of the largest tonnage that the capabilities of the port will permit; ships of which the draught allows them to enter only at high water.

Length from head to head, not including platbands..	59^{m},00
Thickness of floor..........................	3 ,00
Maximum thickness floor at upper mitre-sill........	4 ,60
Versed sine and projection of mitre-sill.. 0^{m},35 and	4 ,10
Length of gate recesses........................	12 ,25
Depth of same.............................	1 ,70
Height of top relative to lower or tail floor.........	8 ,09
Depth of water at spring-tides....................	6 ,35
Depth of water at neap-tides....................	5 ,35

The thickness of the side-walls is 3^{m},60 at the top and 5^{m},35 at the flooring; this difference is given by five horizontal offsets; the quay walls are 2^{m},50 at the top and 4^{m},70 at the base.

The lock was built upon a soil composed of fine sand in an enclosure of sheet-piling. The floor, which is set out in an arc with a chord of 21 metres and a versed sine of 15 metres, rests on oak piles 3 metres in length and 2 metres apart in all directions. Their ends are let 0^{m},40 into the beton that forms the bed of the flooring, and which is 1^{m},80 in average thickness. The upper layer is 1^{m},20, of which 0^{m},85 are in brick and 0^{m},35 in squared stone. All the filling in is in home made bricks, and the facings, as well as the paving of the floor, are in Marquise (Pas-de-Calais) limestone, of which the model offers a specimen.

The platbands are each 8 metres in length. The upper one is composed of a layer of clay 1^{m},40 in thickness, and is protected by jointed planking fastened to the wales of the isolated piles. The lower or tail floor consists of a layer of clay, a bed of fascines, a layer of packing, and finally one of rough stone. The total average thickness is 1^{m},60. Lines of sheet-piling protect the platbands.

The lock is closed by a pair of ebb-gates abutted by *portes-valets*. Each leaf is 11^{m},682 in breadth, 8^{m},34 in height and 0^{m},90 in thickness at the middle. The frame comprises the heel-post 0^{m},60 by 0^{m},55, the mitre post 0^{m},57 by 0^{m},53, upper and lower cross-pieces, 0^{m},43 and 0^{m},45 in depth, and nine cross-braces in red pine. The horizontal pieces are convex on the upper side of the gates.

Each of the cross-beams is formed of three pieces bolted to each other so as to form a truss-beam. The cross-braces, 0^{m},72 in thickness at the middle, are made of two similar pieces. The depth of the four lower cross-pieces is $0^m,35$; that of the five others $0^m,30$. Their distance apart, $0^m,25$ for the four lower intervals, increases gradually from $0^m,275$ to $0^m,50$.

A double diagonal brace, $0^m,40$ by $0^m,25$, binds the horizontal pieces, and is supported by the foot of the heel-post. There are also two double iron ties $0^m,13$ by $0^m,03$ with screw nuts in the upper part; one of these ties starts from the head of the heel-post, the other from the top of the diagonal brace, thereby preserving the rigidity of the leaf.

Five pairs of vertical stiffeners, $0^m,30$ by $0^m,25$ and $0^m,10$ square, bind all the cross-pieces, strengthen the middle of the leaf, and transfer a portion of the pressure to the sill. Each upper or head face has a cleading of pine $0^m,12$ in thickness; the lower or tail-face, a cleading of oak, $0^m,06$ in thickness.

Each leaf is provided with three wooden sluices, 1 metre in height by $0^m,90$ in breadth in open-work, and worked by a rack and pinion jack.

The ebb-gates are worked by means of chains fastened to the faces of the mitre-posts, and geared to winches on the respective banks.

Small jack-screws fixed to the return faces of the gate recesses, hold the mitre-posts open and prevent their displacement by the movement of the waves.

The portes-valets are constructed on the same principle as the ebb-gates. Each has a trapezoidal frame in home grown oak, with a breadth of $11^m,27$, a height of $8^m,40$ at one extremity and $6^m,30$ at the other; also five intermediate cross-pieces, of which the breadth is $0^{m},45$, with a thickness varying from $0^{m},30$ to $0^{m},45$; their distances measured along the heel-post, are successively $2^{m},75$, $0^{m},63$, $0^{m},64$, $0^{m},30$, $0^{m},55$, $0^{m},66$.

A double diagonal brace in oak, $0^{m},40$ by $0^{m},15$ forming ties, and two double iron ties $0^{m},13$ by $0^{m},03$, secure the rigidity of the frame, strengthened in addition by a pair of vertical stiffeners $0^{m},35$ by $0^{m},15$, and by various iron mountings.

The works of the lock were executed from 1856 to 1860.

The total cost, without the swing-bridge, but including 160 metres of quays to the approaches, amounted to the sum of 1,331,214 fr. 39 cent., thus divided:

Lock and walls of quay..............	$1,257,623^{f}$ 54
Gates............................	67,316 40
Working machinery.................	6,274 35

The works were planned and executed by MM. Cuel and Decharme, engineers in chief, and Plocq, resident engineer « des Ponts et Chaussées ».

XXIV

PORT OF HAVRE.

BASIN OF THE CITADEL.

Drawings on scales varying from $0^{m},001$ to $0^{m},04$.

This basin comprises two wet docks, which communicate, on one side, with the port, by a lock with chamber, on the other, with the basin of the Eure by a simple lock, — three graving-docks of graduated dimensions, and two discharge or scouring locks.

The 3 navigation locks have a uniform width of 16 metres from the level of the top of the quay walls of the dock. The side walls have an incline of one eighth.

The tail or lower sill of the chamber has been placed on the same level with the bottom of the port, or $1^{m},65$ below the zero of the marine maps. As the guiding mark of opening and closing the gates of this lock has been fixed at $5^{m},30$ above the sill, vessels drawing 5 metres of water can enter the chamber, and thence pass into either of the basins, $4\frac{1}{2}$ hours after high water, i. e. about 3 hours after the closing of the tide gates. Similar advantages attend their departure; in fact, vessels leave the lock-chamber at the same time that steamers waiting in the port are able to put to sea.

It would have been useless to give to the upper gates the depth given to the tail-gates of the chamber. Accordingly their height has been reduced 2m,30, and their sill made flush at 0m,65 above the zero of the maps, so that at the weakest neap flood, vessels drawing 5 metres of water can pass freely through these gates.

The chamber is 80 metres in length by 55 metres in width, and the quay walls are 11m,30 in perpendicular height above the foundation. The bottom of the chamber is 0m,50 lower than the tail-sill, and owing to this arrangement, the mud carried into the port can accumulate at the bottom of the chamber, for a considerable period, without the necessity of dredging to facilitate the evolutions of vessels. Filling the chamber is effected by four triple sluices in the upper gates, and by two culverts, each 1m,94 in section, which open on the chamber. This operation is accomplished in an average time of ten minutes. Two other culverts, of the same section as the preceding, serve to empty the chamber, that is to say, to lower the plane of the water 5m,30 above the upper sill of the tail-gates. Thirty five minutes are necessary for this second operation.

The dock is divided into two parts by a mole. The northern part, which serves as a channel of evolutions between the Eure and the Citadel basins, is 110 metres wide; the southern part is only 80 metres, and the space between the extremity of the mole and the entrance to the dry docks, is 100 metres. The quay walls have a uniform height of 9 metres above the foundations. The foot of the walls and the bottom of the basin, are 0m,50 lower than the sill of the upper gates of the chamber and of the communication with the basin of the Eure, consequently a certain time must elapse before the mud deposited by the rising tides, can impede the evolutions of vessels in the basin.

The three dry docks, that constitute the new establishment for repairs, have been constructed in the south-east bank of the basin of the Citadel. They are respectively 45, 55, and 70 metres in length on the blocks; 11, 13 and 16 metres in width at the entrance lock, measuring from the top level; 7 metres, 7^{m},50 and 8 metres in height above the sill of the entrance. The side walls and banks of these docks are inclined one eighth.

The dry docks are closed by floating gates in sheet-iron, with a foot-bridge at the top. They are fitted with sluices which fill them when necessary. Each dry dock is in direct communication, on the one part, with the port, by means of culverts closed by double iron sluices, the aperture of which is at the foot of the upper platband of the entrance lock; and on the other part, with a common shaft with which is connected a steam-pump.

At spring-tides, the three dry docks are completely drained at low water by means of the culverts which discharge into the port. At neap-tides this is not the case, and it is necessary to pump out a channel 1^{m},90 in depth for n° 1 dock, 2^{m},40 for n° 2, and 2^{m},90 for n° 3.

The two scouring locks are placed side by side, and open into the basin of the Citadel, between the upper gates of the chamber and the dry dock n° 3, and into the port near the southern wing wall of the tail-gate of the lock.

Each lock is 6^{m},20 in breadth by 7 in height, and is closed by a turning gate and a pair of sluices. The gates open and shut by the action of the current, and the object of the sluices is to protect them from the swell in the port.

The inverts are horizontal and made flush at 2^{m},15 higher than the zero of the maps, for a length of 28 metres starting from the upper sill; they then incline, following a regular slope, so as to reach, at the lower aperture, the level of the bottom of the port (1^{m},65 below zero). The total difference between the upper and lower level, is therefore 3^{m},80. Besides the basin of the Citadel, the supply reservoir of the discharge gates includes the basin of the Eure, the entrepôt dock and the basin Vauban, making altogether a superficies of 39 hectares. From this calculation it follows that, by lowering the water of the basins only one metre, which at spring-tides would in no wise inconvenience navigation, the scouring locks could throw a volume of 390,000 cubic metres of water into the port, at ebb-tide.

The lower end of the lock of the chamber and the lock of communication with the basin of the Eure, are each crossed by an iron swing-bridge with a single flap and two carriage ways. Each bridge is 35^{m},17 in length, 6^{m},94 in width and consists of two girders, forming the parapets, increasing in height from the extremities to the point of greatest tension. These girders are connected transversely by joists, strengthened by gussets and cross-braces, to which is bolted the wooden flooring that supports the double carriage way, the two foot-ways, and the ridge separating the two road-ways.

The lock-gates are of timber and are double. They are formed of an oaken frame, the uprights of which are connected by cross-pieces in pine. A rigid pine planking is laid over the cross-pieces. Besides the tenons, the connection of the various parts of the work is secured by means of rows of bands and a double wrought iron tie.

The upper gates are $7^m,40$ in height. The lower gates, which are $0^m,50$ lower in level than the upper gates, are $9^m,25$ in height. In order to protect them from the attacks of the teredo worm, all the wood-work has three coats of metallic paint, and is covered with nails to a level corresponding with high water at neap-tide.

The balance gates and discharge sluices are also in timber. Each of these gates is formed of a single leaf, $5^m,70$ in height, by $6^m,16$ in breadth, divided into two unequal parts by the vertical axis on which it moves. The difference in breadth is $0^m,06$, and in the largest side a turning sluice is placed, the dimensions of which are so arranged that when it opens, the pressure of the water preponderates in the smaller leaf of the large gate.

The floating gates which close the three dry docks of the Citadel, are in plate and angle iron. The frame pieces are put together on a keel and bound by strong floor timbers, a keelson, longitudinal pieces, a water-tight deck, a foot-bridge and diagonal stays. The plates of iron are riveted clinker fashion on the angle irons, and make the chest perfectly water-tight.

The water-tight deck divides each caisson into two distinct parts. The lower part forming the float, contains the ballast, and should be always dry. This ballast is so regulated that the caisson left to itself floats on a level with the water-tight deck. The other part can either remain dry, or be put in communication with the water of the dock. With this view, two or three sluices, according to the dimensions of the caisson, open in each side of the hull on a level with the water-tight deck. Under the foot-bridge and in the same compartment, is a chest, the bottom of which is above the level of the highest tides, and which serves to receive the water intended to sink the caisson.

To accomplish this, the sluices being open, it is only necessary to introduce the water into the upper chest. The equilibrium is immediately disturbed, and the water from the basin flows into the upper compartment, above the water-tight deck, and the caisson sinks until the weight of the volume displaced by the plate and the angle-irons, is equal to the weight of the water introduced into the chest. And as under the most unfavourable circumstances the volume displaced is of little importance, a small quantity of water is sufficient to sink the caisson.

The cost of all these works, including the reconstruction of the eastern quay wall of the port and the expenses of survey and superintendence amounted to 10,100,854 fr. 04 cent.

These works were constructed from 1865 to 1871, and directed by M. Hérard, engineer in chief, and M. Bellot, resident engineer «des Ponts et Chaussées».

XXV

CAISSON OF THE COFFER-DAM

OF THE BASIN AT BREST.

Drawings on scales varying from 0^{m},004 to 0^{m},10.

In 1867, it was found essential to replace the basin of oldest date in the port of Brest. The new one required a length of 112^{m},70, a breadth of lock 21^{m},70, and 8^{m},50 of water in the lock at the lowest neap-tides. For this purpose it was necessary to construct a coffer-dam, founded on the compressed air system, by means of a unique caisson 27 metres in length by 8^{m},50 in breadth and 10^{m},50 in height, attached, at one end, to a wall of masonry previously built, and at the other, to the solid rock; also to erect a general wall upon the whole.

This work was remarkable for the exceptional dimensions of the caisson, the necessity of removing the apparatus, and the difficulties occasioned by tidal movements.

At the bottom of the caisson was a large working chamber strengthened in various ways, and divided into three parts, each provided with a shaft surmounted by an air-chamber.

Above this first chamber was a second, 21 metres in length, and intended to facilitate the taking to pieces that part of the caisson which was to be removed at the termination of the works, in order to leave the entrance of the basin clear of obstruction.

The lower part, comprising the working chamber, was obliged to be lowered sufficiently to allow the free passage of vessels; and it was considered more advantageous to preserve it, as a protecting wall in front of the lock than to remove it. This conviction suggested the plan of a double working chamber, and a caisson in two parts, each of which constituted a separate caisson, and was fastened to the other by bolts.

Above the second working chamber was an open compartment, which could be closed and rendered air-tight if necessary. This compartment was divided into two parts, one 21 metres in length, corresponding to the portion of the caisson which was to be removed, the other 6 metres in the line of the quay wall, and intended to remain in its position.

At each extremity were three large grooves, 1 metre in section, descending vertically to the bottom of the lower chamber, of which the side opposite the rock was extended by an inclined plane, in order to fit the edge of the caisson.

These grooves were open next to the rock, and were destined, by filling them with beton, to form an air and water-tight connection between the caisson and the side of the rock. A man-hole was contrived in the lower part, in the inclined plane just mentioned, so that from the working chamber, the grooves could be cleaned before filling them with beton.

In July 1867, this caisson was put together in one of the graving docks of the port of Brest, and when finished weighed 170 tons.

In September it was ballasted with stone-work, increasing the weight to 240 tons, then taken like a boat to the spot required, and grounded in the precise position previously assigned to it.

At the commencement of the sinking the work suffered considerably from tidal agitation, until the caisson was sufficiently weighted to admit of injecting air, and carrying on the work continuously in the chamber.

Two blast engines established on the bank, and moved by a 30 horse-power engine, conveyed to the working chamber nearly 400 cubic metres of air per hour.

A portable engine, also on shore, worked the three hoists established in the shafts by means of transmission lines and pullies.

The excavated earth was discharged into mud-lighters alongside the caisson.

To avoid injury to the edge of the caisson, by the weight of the stone-work, it was supported inside the working chamber, by shores resting on the rock, and tightened at the upper part by means of wooden soles and wedges.

The masonry above the working chamber, was built with mortar of 1 cubic metre of sand to 0^{cm},55 of hydraulic lime and 100 kilogrammes of Portland cement. The working chamber was filled in with rubble, and the mortar was composed of 1 cubic metre of sand to 0^{cm},45 of hydraulic lime, and 200 kilogrammes of Portland cement.

The portion of the coffer-dam, above the side of the caisson, was constructed without difficulty at low water. The junction of the caisson with the sides of the basin required particular care, and necessitated the employment of diving apparatus in order to thoroughly clean the grooves.

The work was finished in April 1868. The filtration was only 10 cubic metres per hour.

In April 1869, the works of the basin being finished, the demolition and removal of the coffer-dam were proceeded with.

For this purpose, before letting the water into the basin, and by continual pumping, the part of the caisson to be removed was detached as completely as possible from the masonry to which it adhered. This was accomplished by opening two little galleries at the two extremities, to nearly 50 centimetres from the exterior facing.

The water was then allowed to enter the basin. At the rising of the tide, the masonry above the caisson was demolished.

The stone-work in the open compartment was also demolished at the flow of the tide, but pumping was necessary to carry out this work.

The demolition of the masonry in the second working chamber, was commenced in open air. A longitudinal gallery was made, before replacing the air chambers on the shafts, and the work was then continued with compressed air. The masonry was then removed.

Then, the caisson being sufficiently freed from weight, the bolts holding it were drawn, and it floated by pumping out the upper compartment.

This operation was successfully performed on the 26th June 1869.

In short, the construction of the coffer-dam was accomplished in seven months, and its demolition in two months and a half.

These works were executed by contract, at a cost of 376,000 francs, without reckoning 4,640 francs for the extraction and clearance of wood, iron, etc., from beneath the edge of the caisson.

The execution of the work was directed by MM. Dehargne, engineer in chief, director of hydraulic works, and Rousseau, resident engineer.

XXVI

PORT OF SAINT-NAZAIRE.

A perspective view.
A geometrical plan on a scale of $\frac{1}{2000}$.

The port of Saint-Nazaire is situated on the right bank of the Loire, at the mouth of the river, and is but of recent creation. Twenty years ago, the place now occupied by the dock was only a small creek or bay, frequented by pilot and fishing boats.

In front of the port is a roadstead, formed by the enlargement of the great channel of the Loire. There is a depth of 8 to 15 metres at low water, and the bottom being composed exclusively of mud, vessels find excellent holding ground in this roadstead. There is very little swell, and the smoothness of the water is owing to the rocks and sandbanks, which break the force of the waves at the mouth of the river. The mole, constructed at the point of the old town, also contributes greatly to the security of the anchorage.

At the entrance of the Loire there is a depth of at least $7^{m},70$ at high water of neap-tide, and $9^{m},20$ at spring-tide.

General description of the port. — In its present condition, the port of Saint-Nazaire consists of a channel lined with wooden jetties and terminating in two locks which form the entrance of a floating dock, surrounded by large quays. The roadstead supplies the place of an outer port, and vessels moor at the extremities of the jetties and are afterwards towed up the channel. When the basin is open, they pass directly through the locks.

Nature of the ground. — The basin and locks have been established in a bay having a mud bottom with an underlying stratum of compact schistous rock. They were constructed by means of a banked up enclosure, formed of the excavated earth and constituting a coffer-dam. Many difficulties attended the execution of this work, but the talus in loose stone, 4 in base by 1 in height, has enabled it to resist the action of the water.

This embankment, enlarged by the excavations of the basin, forms an earth-work which answers the double purpose of fortifications, and of shelter from the wind.

Dimensions of principal works, and height of tides. — Before entering into details, it will be useful to furnish these particulars:

Coping of side-wall of great lock, and flooring of new jetties	10^{m},60
Coping of other locks and flooring of old jetties	13 ,60
Rails round basin	14 ,40
Coping of quays of basin of Saint-Nazaire and Penhouet.	14 ,60
High water at equinoctial spring-tide	15 ,08
High water at ordinary spring-tide	15 ,50
High water at neap-tide	17 ,00
Low water at neap-tide	19 ,30
Low water at ordinary spring-tide	20 ,50
Zero of annual register of tides	20 ,83
Low water at equinoctial spring-tide	21 ,00
Zero of gauge at Saint-Nazaire	21 ,10

Lock-sill to chamber of 13 metres in breadth	23^{m},10
Bottom of part south of basin of Saint-Nazaire	23 ,20
Bottom of part north-west of Saint-Nazaire	24 ,00
Lock-sill 25 metres in breadth. Chamber same depth	24 ,30
Bottom of part north-east of basin of Saint-Nazaire	24 ,50
Carpenters' bar	24 ,73
Bottom of basin of Penhouet	25 ,00

The channel was opened through a bank of mud, which at high tides reaches the end of the south jetty, and, on the north bank, to twenty metres distance from the wing-wall of the lock, where at low water there is always a depth of 2 or 3 metres. It is properly dredged, and ships always find 7 metres of water at high neap-tide.

Jetties. — Wooden jetties extend along the two banks of the channel. The uprights are 3^{m},75 apart from centre to centre, and have an exterior and interior diminution of one tenth.

The flooring is 4^{m},50 in breadth, reduced to 3^{m},36 between the side-rails. It is on a level with the coping of the locks, 1^{m},48 above the equinoctial tides.

All the wood-work is in Prussian pine. Worms made their appearance for the first time in 1859, and have caused considerable damage.

In every part of the north jetty joining the lock, it has been necessary to use hard stone to a depth of several metres below low tides, where piles could not be driven. The method adopted for this part of the foundations was the same as that previously employed for lengthening the side-walls of the locks. The uprights were fixed in shafts of stone-work 6 metres square, carried down to the rock by its own weight, the mud being taken out from the inside⁽¹⁾. These holes, made flush at the sides (18 metres), received the uprights.

This mode of construction has succeeded very well. Carried to perfection by means of compressed air, it has been successfully employed in the foundations of great bridges and similar works, where the defective nature of the ground presented extraordinary obstacles.

Locks. — Two locks occupy the channel⁽²⁾. They have their foundations entirely upon the rock. The largest, constructed with the view of admitting Transatlantic paddle-steamers, is 25 metres in breadth. It is a simple lock with two pairs of gates, one of which can serve in case of accidents or repairs⁽³⁾. At the lowest point of the sills, which take the form of an arc, there is $7^{m},30$ of water at the lowest high tides, and at spring-tide $8^{m},80$.

The small lock is 13 metres in breadth, and has a chamber 60 metres in length, capable of being used from half-flood till half-ebb, that is to say, six or seven hours. When a large ship requires to enter or leave the basin, the lock of 25 metres can remain open two or three hours.

Building the side-walls of the great lock. — The cappings

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(1) The details of these shafts may be found in the *Collection of drawings at the École des Ponts et Chaussées*, vol. I, part III. Consult also the description of the coffer-dam with shafts at the port of Lorient, published under the direction of the Ministry of Public Works, and of which a model was shown in the Universal Exhibition at London 1862.

(2) One of these locks is described in the *Collection of drawings at the École des Ponts et Chaussées*. See the account given in vol. I, part III.

(3) The model of these gates appeared in the Universal Exhibition at London 1862.

The description is found in the notice published on this occasion, by the Ministries of Agriculture, Commerce and Public Works.

of the locks are $1^{m},48$ above high water of the equinoctial spring-tide. In order to facilitate the entrance of Transatlantic steamers, the height of the masonry of the walls in the perpendicular of the facings, has been raised 3 metres, with the view of guiding the outer frame of the paddle-boxes. Above the recess, strong iron girders are placed, serving also as foot-bridges.

Basin. — The locks terminate in the basin, of which the dimensions are as follows :

1st part	Length	580^{m}
	Breadth	160
2nd part	Length	140
	Breadth	90

The superficies is $10^{h},40$.

All the lower part has been excavated to a depth varying with the gneiss schist, which, simply covered at certain points with a thin stone facing, forms the body of the quay walls.

The depth of water maintained in the basin is always greater than that of high neap-tide (17 metres). The following depths are found at this level :

Opposite the locks and the quay des Frégates	$7^{m},50$
The length of the quay de la Marine	7 ,10
Between the quays of the Loire, Vieille-Ville and Commerce	6 ,20
Between the quays Wattier, Henri Chevreau and Jégou, from $6^{m},20$ to	7 ,00

The basin is surrounded by vast quays connected with the railway terminus by lines of rails.

The port of Saint-Nazaire being especially a port of transit, almost all goods pass directly from the vessels into the trains, or into lighters which go up to Nantes, and vice versa.

The total length of the quays is 1,500 metres. A great part of this space is occupied by the public services and the General Transatlantic Company. The lands situated behind the Marine and Jégou quays have been granted to this Company, and sheds, stores, work-shops, etc. have been established, containing all things requisite for the service of the two lines of Mexico and the Antilles.

The 860 metres of quays are utterly inadequate to the requirements of commerce, and the completion of a second basin is looked forward to with impatience.

Clearing the port of mud. — By referring to the commencement of this notice, it will be seen that the channel of the port of Saint-Nazaire was opened through a bank of mud, which is constantly being renewed by the tides. It was necessary to act promptly in this matter, and the problem was solved in a manner at once satisfactory and economical, by the aid of pumping and discharging boats, the same engine working both pumps and propeller. 1,000 to 1,500 cubic metres were taken from the port to the roadstead, and there discharged by opening the valves.

An ordinary dredging-machine is sufficient for those parts of the port where, for various reasons, the mud is not sufficiently liquid to admit of being pumped, which is the case when the density exceeds 1,200.

At the present time the importance of dredging operations is fully recognised and the cost of them is accurately known. To maintain a sufficient depth of water for the movements of large vessels, it is necessary to remove the following quantities every year.

In the basin (from a superficies of 10^{h},40)...	163,000^{cm}	of mud.
In the channel (from a superficies of 1^{h},35)..	193,000	
Total..................	356,000^{cm}	of mud.

Which is equal to 1^{cm},55 per square metre of the basin, and 14^{cm},27 per square metre of the channel.

Three fourths of this mud is pumped, the remainder is dredged.

These operations are carried on at the following cost per cubic metre, for pumping and discharging.

Coals, repairs and labour......................	0^{f},15
Interest and payments for working material..........	0 ,24
Total cost......................	0^{f},39

EXTRACTION AND DISCHARGE OF MUD DREDGED.

Coals, repairs and labour........................	0^{f},35
Interest and payments for working material...........	0 ,37
Total cost.....................	0^{f},72

Expenses. — The cost of the works of the Saint-Nazaire basin may be divided as follows :

Enclosure dam............................	295,000^{f}
Earth-works and masonry of basin.............	5,424,000
Construction of jetties and excavating channel.....	1,434,000
Lock-gates, sluices, etc......................	693,000
Various works.............................	280,000
Total....................	8,126,000^{f}

New works in course of construction or planned. Basin of Penhouet. — The inadequacy of the basin at Saint-Nazaire was soon ascertained, and it was decided that a second basin should be formed in the bay of Penhouet. The cost is estimated at 18,500,000 francs, and at this time the works are being prosecuted with the greatest activity.

It was impossible to form a direct entrance from the roadstead to the basin of Penhouet. To attain any great depth, it would have been necessary to advance considerably into the open and deep water, and the projection occasioned by the formation of a new channel, would have infallibly closed the present entrance. Under these circumstances, it will be necessary to enter the second basin by passing through the first.

The circular dam or embankment, that surrounds and protects all the work-shops, was finished in 1865, and is now being enlarged with the soil excavated from the basin.

Lock-chamber. — The communication between the two basins will be effected by means of a lock-chamber 25 metres in breadth, and $7^m,30$ in depth of water at neap-tide on the sills, which are horizontal.

Four pairs of gates will enable the lock to be worked in both directions, in order to control the level of the water in the basin of Penhouet, and to prevent the accumulation of mud there. The length of the lock-chamber is 130 metres.

Two large culverts 2 metres in breadth pass through the whole length of the chamber walls and connect the two basins. They communicate with the chamber by means of subordinate culverts. Heads, or reserve pressures of water have been created, passing through small culverts with outlets $0^m,20$ in diameter, level with the bottom of the gates. They will serve to produce rapid discharges of water, and will obviate the necessity of clearing the channel by hand labour.

Iron bridges for the general traffic will be constructed at each end of the lock.

Quay walls. — It will not be possible to build walls all round the basin. The precarious nature of the subsoil will not allow of one in the mud valley which crosses the basin. At the south-east angle and the middle of the west quay. stone packing, resting on large masses of stone, is substituted. Wooden platforms enable vessels to come alongside the quays.

The quay walls are $10^m,40$ in height, and are founded upon the solid rock, but under different conditions. While some parts are composed of simple stone facing, others will have to be carried to a depth of 10 and even 12 metres below the bottom of the basin.

Three graving docks, also founded on the rock, are to be established in the basin of Penhouet. The following figures give their dimensions.

DOCK.	BREADTH of entrance.	LENGTH.	DEPTH below high water at neap-tide.
N° 1	$25^m,00$	135^m	$7^m,30$
N° 2	16 ,00	115	5 ,50
N° 3	13 ,00	95	3, 50

Head of water. — In creating at Saint-Nazaire a second basin more than double the size of the first, the reduction of the accumulation of mud to the lowest proportions, became an imperative necessity.

With this view, a special head of water will discharge itself into the roadstead by means of sluices. These will not be worked more than two or three times a month, and always in calm weather, when the upper part of the water is not heavily charged with mud.

The head of water will be 30 metres in breadth, and the sluices will be worked by lowering, in such a manner as to take only the surface water, as may be deemed convenient.

Building-yards. — Between the basin and the roadstead, sufficient space has been reserved to establish building-yards. One part is already taken up by the General Transatlantic Company, and five of their great iron steamers have been constructed there.

Cost. — The cost of the basin of Penhouet has been estimated at 18,500,000 francs divided as follows:

Acquisition of ground	2,035,400f
Enclosure embankment or dam	500,000
Earth-works	3,800,000
Lock 25 metres in breadth	2,900,000
Quay walls and stone packing in basin	4,250,000
Head of water	500,000
Three dry docks	2,800,000
Various works	600,000
Employment of lock as temporary dock	250,000
General and unforeseen expenses	864,600
Total	18,500,000f

The engineers who have successively assisted in plans and in the execution of the works of the port of Saint-Nazaire are MM. **Cabrol** and **Plantier** as engineers in chief directors; A. **Jégou**, **Chatoney** and **de Carcaradec**, as engineers in chief; **de la Gournerie**, A. **Watier**, **Leferme**, **Révol** and **Pocard-Kerviler**, resident engineers. M. **Morel** (Joseph) has been attached to these works as conducteur since their commencement.

XXVII

LOCK-GATES OF SAINT-NAZAIRE

(LOIRE-INFÉRIEURE).

Model on a scale of $0^m,01$ (one tenth).
A drawing on scale of $0^m,01$ (one tenth).

The port of Saint-Nazaire has two locks 25 metres in width.

The first puts the basin into communication with the roadstead, and is furnished with two pairs of wooden gates; the second will subsequently connect the basin of Saint-Nazaire with that of Penhouet, now in course of construction, and has one pair of iron gates. This lock is temporarily used as a graving dock.

The maximum pressure, supported by the two pairs of wooden gates, is 6 metres, which corresponds to the difference between flood and ebb of equinoctial spring-tides.

At strong tides, when the graving-dock is dry, the iron gates have to support a pressure of 10 metres of water. This difference necessitated giving them great power of resistance.

As there is no appreciable difference between the dimensions of these gates, in respect to height and breadth, a comparison between the two systems may possess some interest.

§ I. — Cross-gates.

Principal dimensions. — The lock of the port of Saint-Nazaire has an opening of 25 metres, and each of the leaves is $15^{m},96$ in total breadth and 10 metres in height.

The thickness at the principal post is $0^{m},60$, and at the middle $1^{m},60$. The tail-face is flat, but the head-face is curved to an arc of a circle concentric to one passing through the interior angle of the chief posts and the extremity of the mitre-sill.

Construction of the gates. — Each leaf consists of sixteen wooden cross-pieces each formed of a tie-beam of $0^{m},40$ and four stove-bent pieces $0^{m},20$ in thickness. The two inner pieces join the beam to which they are fixed by the medium of iron plates strengthened by angle-irons; the two others extend to the extremities of the tie-beam. A system of brackets, tie-bands and bolts completes each of these cross-pieces, which are in fact, trussed beams.

Thirteen of the cross-pieces which are only $0^{m},37$ in thickness are superposed to a height of $4^{m},80$ at the lower part of the leaf; the other three, $0^{m},40$ in thickness, are placed at distance from each other of $0^{m},95$, $0^{m},90$ and 2 metres. Wooden wedges and wrought iron frames retain the latter in their positions. Fifteen vertical wedges or keys, driven in with a monkey, after the placing of the beams, complete the frame-work.

In short, there is neither heel-post nor mitre-post.

The cross-beams extend the whole length of the leaf, and are simply bound at the ends with iron rings $0^{m},010$ in thickness mutually strengthened by means of inner junction plates consolidated by bands of iron plate and bound from one post to the other by three iron cross-braces; two of which clasp the solid part of the leaf while the third rests on the upper cross-beam.

The cast iron pivots attached and bolted to the upper and lower cross-beams are also riveted to the last rings of the post.

The rounded up-stream face of the gate has a vertical plank cleading $0^{m},086$ in thickness, and a watertight cleading of sheet-iron $0^{m},005$ in thickness, is fixed on the plane tail-face between the two upper iron cross-pieces.

The real novelty, presented by the gates of Saint-Nasaire, is the absence of heel and mitre-posts. Special and expensive woods are therefore no longer necessary for the construction of gates having great width of opening and a considerable depth of water; neither is there reason to fear the dislocation which causes the destruction of all gates. Wood of a resinous nature and of ordinary dimensions, is all that is required. The idea of vertical bonds, obtained by means of interior keys or ties to the leaves, appears also excellent, but it had been previously applied to gates having an opening of $16^{m},50$.

The gates constructed in 1856 were made entirely of Prussian pine, while those of 1858 were in pitchpine. Since their erection, they have worked without accident or the least dislocation.

Cost. — The cost price of the pair of gates of 1858, may be divided as follows :

243^{cm},50 frame-work in position at 336^{f},37^{c} per cubic metre[1]	32,027^{f},	85^{c}
16,994^{k},5 galvanised sheet-iron at 1^{f},70 per kilog.	28,890	65
20,260 kilog. sheet-iron not galvanised at 1^{f},50 per kilog	30,390	00
16,846 kilog. galvanised iron-work at 1^{f},40 per kilog	22,184	40
12,647 kilog. iron-work not galvanised at 1^{f},20 per kilog	15,176	40
5,006 kilog. cast iron at 0^{f},626 (average price)	1,881	76
Caulking	2,294	44
Painting, coating and mastic	6,755	78
Sundry expenses	2,863	03
Total	192,464^{f},	31^{c}

It must be remarked that at the present time, this price would be considerably diminished by reason of the abolition of duties on raw materials.

The two pairs of gates of 25 metres opening, at the port of Saint-Nazaire, were constructed on the same system, the first in 1856, by the late M. **Watier**, engineer of « Ponts et Chaussées », and on his plans; the second by M. **Leferme**, engineer « des Ponts et Chaussées », in 1858.

The works were commenced under M. **Jégou**, engineer « des Ponts et Chaussées »; continued and finished under the direction of M. **Chatoney**, engineer in chief des « Ponts et Chaussées ».

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(1) This sum includes the wood which is calculated at 169^{f},50 per cubic metre of frame-work.

§ II. — Iron gates of the lock of Penhouët,
TEMPORARILY UTILISED AS A GRAVING DOCK.

Principal dimensions. — These gates have the same form and principal dimensions as the wooden gates previously described, almost the only difference being that their height is 10^{m},25, instead of 10 metres.

Composition of the gates. — Each leaf consists of twelve cross-pieces, three vertical girders forming uprights, and two other vertical girders at the extremities, constituting heel-post and mitre-post.

The cross-pieces are 0^{m},90 apart, from centre to centre, and are in the form of a double T girder. The web is in iron-plate, 0^{m},02 in thickness for two cross-pieces, and 0^{m},015 for the ten intermediate ones. The flanges are formed of two angle-irons, 0^{m},160 by 0^{m},110 and 0^{m},016, with the arms corresponding to the skin, which is 0^{m},010 in thickness, and the cover-plate, which is 0^{m},335 in breadth by 0^{m},015 in thickness.

The uprights are arranged in a similar manner; nevertheless the girder is not continuous, but is composed of successive rectangular lengths, riveted together at the ends in the same vertical plane, and intercepted by the webs of the cross-pieces. The two flanges of the girder are not parallel, and in each of the intervals which separate two cross-pieces, the web is pierced by two elliptic man-holes, which give access to the interior, for the purpose of scraping and painting.

The outer skin is continuous, and extends over the whole of the frame. It is formed of sheets of iron 0^{m},010 in thickness, covering accurately each of the rectangular spaces, formed by the cross-pieces and the girders. Five vertical rows of frames, in angle-irons $0^{m},060$ by $0^{m},06$ to $0^{m},009$, placed at regular intervals between two successive uprights, constitute intermediate supports to the sheets of iron forming the skin.

Ballast. — Each leaf weighs 140 tons in the air, and as it would float in the water, before being completely submerged, ballast is requisite, and for this purpose it is divided into two water-tight compartments by the fourth cross-piece, counting from the top.

The upper compartment serves as a receptacle for ballast, which is furnished by the water in which the gate is immersed. The water has free entrance and egress, by the apertures in the up-stream and down-stream skin, so that the ballast is self-moving, and is proportioned in quantity and weight to the level of the water in the basin. The apertures are, however, fitted with valves, capable of being opened and shut at discretion from the foot-bridge, but, as a matter of fact, these valves always remain open.

The lower compartment acts as a float, and remains constantly free from water. Water-tight tubes opening on the foot-bridge, and provided with fixed ladders in wrought iron, give access at all times to the upper compartment.

By means of the spontaneous action of the ballast, with a variation of water level in the basin attaining to $1^{m},30$, and in exceptional circumstances $1^{m},45$, according to the tides, the actual weight of the gate with its ballast, is maintained at between 10 and 12 tons.

Movable friction rollers. — Each gate has nevertheless been furnished with two rollers, which travel on circular iron ways let into the down-stream flooring.

These rollers can be taken up if necessary. They are set in a movable frame, inside the gate, reaching above the second cross-piece, reckoning from the top. On this cross-piece is fixed a jack-screw, by means of which the frame and roller can be taken up at the same time.

To prevent the entrance of the water, the vertical supports of the frame pass through the lower and fourth cross-piece by the medium of a stuffing-box, and for greater security, each frame is enclosed in a perfectly water-tight shaft. For the rest, the tubes that pass through the ballast chest, are amply sufficient to give access to every part of the float, if it were required to isolate them definitively.

Maximum strain on the iron. — The calculations of resistance have been made by the method of M. Lavoinne, engineer, whose theoretical researches corroborate in a remarkable manner the results of experiments previously made at Havre by M. Chevallier, inspector general. The condition imposed was that, even in the parts sustaining the greatest weight, the iron should only be subjected to a strain of 4 kilogrammes per square millimetre of section, in place of 6 kilogrammes, the figure generally admitted in French constructions of iron.

Effects of oxydation. — The injurious effects of oxydation have been provided against, and upon this head, it may be remarked that the gates can be frequently painted in the whole of the interior and on the plane surface. And in addition to this circumstance, experience has shown at

Saint-Nazaire, that the iron submerged in the basin is rapidly covered with a compact layer of shellfish with calcareous coverings, named *cravants*. This casing has nearly the same preservative effect as a coat of paint.

Cost price. — The gates were contracted for by the Ocean Society of Forges and Workshops, for 246,000 fr. in round figures.

These gates were planned and executed in 1871, under the successive direction of MM. Chatoney and Leferme, engineers in chief, and M. Revol, engineer « des Ponts et Chaussées ».

SUMMARY COMPARISON BETWEEN THE TWO SYSTEMS.

In the course of this notice it has been remarked that, while the wooden gates constructed in 1858, were required to support a maximum pressure of 6 metres of water, the iron gates, owing to circumstances, were subjected to a pressure of 10 metres, and that the results of this test have been satisfactory.

The cost price of each of the wooden leaves of the gates was 110,000 francs. The leaf of the same dimensions in iron, cost 123,000 francs.

This cannot be considered a very significant difference, regard being had to the constantly increasing price of timber of large dimensions.

If, in default of direct observations, the relative durability of vessels of iron and wood be taken into consideration, it may be inferred that, for sea-gates, as a question of economy, the preference must be awarded to iron, rather, than to wood, as the material of construction.

XXVIII

BASIN AT THE PORT OF BORDEAUX.

Drawings on scales varying from $0^m,0005$ to $0^m,02$.

The basin at Bordeaux was established with the view of augmenting the capacity of the port, which had become insufficient to meet the requirements of the constantly increasing number of vessels.

This basin will cover a surface of nearly ten hectares, and will be surrounded with vertical quay walls, giving a development of 1,800 metres. In the space allotted to the Transatlantic steamers, the depth of water will be 8 metres, and $7^m,50$ in the other parts. The whole length of the banks will be widened by platforms, having a superficial extent of twelve hectares, for landing and ware-housing goods. The basin will be connected with the Garonne by means of two locks of different dimensions, placed close together. The largest, intended for paddle-wheel steamers, will be 22 metres in breadth and 152 metres in length between the gates. The second will be 14 metres in breadth and 136 metres in length, dimensions sufficiently ample for screw-steamers and sailing vessels. An intermediate pair of gates will divide the chamber into two; one of 60 metres, the other of 76 metres.

Two swing-bridges will be placed at the extremities of the locks, for the continuance of the traffic during the passage of vessels.

The basin will be supplied directly from the Garonne, every time that the level of the tide is higher than that of the water inside. Generally speaking this is the case, but in rare instances, when several unusually low tides succeed each other, the normal level of the basin will be kept up by pumping water into a reservoir.

These works will be made complete by the construction of a graving dock capable of admitting the largest steamers that enter the port of Bordeaux.

This undertaking, commenced in 1869, was delayed by the war, but resumed with energy in 1873, and is now sufficiently advanced to justify the expectation that it will be finished in the course of 1877.

These works have given occasion for the most extensive application of the system of grooved or perforated blocks for foundations. Various circumstances and local conditions had previously necessitated their employment in locks.

Foundation of the locks. — The ground on which these works are constructed, consists of an argillaceous mud, which covers, to a depth of 12 or 14 metres, and an aqueous stratum of sand and gravel 3 or 4 metres in thickness, this latter overlaying a soft mud. It was ascertained by soundings, that the underground water flowed towards the Garonne, at the same time exercising a considerable upward pressure upon the superincumbent strata.

By reason of the level assigned to the lock-sills, the stone-work was obliged to be laid entirely upon the bank of sand. The idea of excavating the soft mud to a depth of nearly 14 metres, could not be entertained on account of the underlying watery strata; it was therefore decided to proceed by means of large blocks of masonry, and thus cause the stone-work to descend by its own weight to the gravel, in order to form the side-walls. These blocks occupied the perimeter of a rectangle 205 metres in length by 57 metres in breadth.

For these masses of stone-work, a uniform breadth of 6 metres was adopted; the length varied from 16 to 35 metres, with a general thickness of 9 metres. Upon the lower half of the wall, separating the two locks, additional blocks have been laid, 9 metres in breadth, 15 in length and 9 in depth. All these blocks are $0^{m},50$ apart, and are pierced by one or more vertical holes or shafts.

A block was sunk, in the first place, to only half its proper or intended depth. When it had completely set, the soil was removed from the shafts, and the block descended until the upper part was level with the surface. The operation was repeated, and the rest of the masonry was made to descend in the same manner.

This part of the work was accomplished without the aid of machinery, so long as the excavation remained dry. But when a depth was reached which left a distance of only 2 metres from the aqueous strata, the water forced its way, and it became necessary to employ a centrifugal pump in each of the shafts. This pump was moved by a portable engine, which at the same time worked the winches used to raise the excavated earth. The sinking was thus continued without difficulty, by workmen at the bottom of the shaft, and was stopped when the block had penetrated $0^{m},80$ into the gravelly sand.

The operations did not always proceed with perfect regularity, and frequently the blocks inclined more or less to one side, in spite of the props employed to steady them. In general however, it was found possible to readjust them, either by skilful management of the excavations, or by a lateral pressure, effected by banking up the block on the side to which it inclined. Sometimes this difficulty could not be surmounted during the descent of the block, but was remedied afterwards by careful digging. These irregularities are explained by the want of homogeneity in the nature of the ground; the numerous obstacles encountered, such as trunks of trees, etc., and the cavities caused by pumping.

The various difficulties being overcome, all the blocks were established in a perpendicular position, with some slight deviations in the ground plan, which were corrected while finishing the facings.

When the sinking of the blocks was completed, the shafts were filled in with beton, for the part below water, and with stone-work for the upper portion.

The intervening spaces between the blocks were also filled in with masonry, and the whole constituted an enclosure, the interior of which was excavated by the aid of pumps, down to the level of the gravel upon which the invert was constructed dry, at 7 metres below low water mark. The work was afterwards proceeded with in the usual manner. At the present time it has attained a height of 4 metres above low water mark, and is perfectly watertight in every part.

Foundations of quay walls. — The successful result of the system employed in laying the foundations of the locks, encouraged its application to the quay walls of the basin, the construction of which had been commenced on piles. This wall is built, for two-thirds of its extent, on a succession of semi-circular arches of 8 metres span, resting on blocks, of which the horizontal section is a square of 5 metres, and which are sunk 1 metre into the gravel. The arches are filled in with solid stone-work without mortar, intended to support the earth behind the wall.

Foundation of graving dock. — In the construction of the locks an attempt was made to sink the foundation blocks by means of dredging, but in consequence of the precarious nature of the ground, it was found necessary to abandon the idea. In respect to the graving dock, the same difficulties did not present themselves, and the foundations were laid by the aid of a dredging-machine. The blocks were laid more regularly, and with a smaller expenditure of time and money, than by the use of pumps.

The whole of the works of the basin and graving dock. including lock, and swing-bridges, caisson, mud-dredge, sluices, and hydraulic machinery, are estimated to cost 14,500,000 francs, of which 11,000,000 francs are actually expended.

The original plan was drawn up by M. Joly (Henry), at that time engineer under MM. Droëling and Pairier, engineers in chief. The actual plans have been made, and the works executed, under the direction of M. Joly (Henry), engineer in chief, and MM. de La Roche-Tolay, Régnauld and Boutan, resident engineers.

XXIX

PORT OF BAYONNE.

CONSTRUCTION OF OPEN JETTIES.

Drawings on scales varying from $0^{m},0\,004$ to $0^{m},50$.

The port of Bayonne is formed by the confluence of the Adour and the Nive, which discharge themselves into the Gulf of Gascogne at a distance of 7 kilometres from their junction. Between Bayonne and the sea, the river has an average breadth of 250 metres. The channel is well sheltered, and there is a depth of from 4 to 10 metres of water at low tide, on a bottom of sand and mud. With these advantages, it would be a place of great importance to navigation, were it not for a bank of gravel, which blocks the entrance of the port.

This bar is in the form of a half circle, which joins the points of sand and gravel forming the embouchure of the river, and envelops them in a sort of enclosure, against which the swell of the gulf dashes freely and breaks with violence.

The waves communicate to the component parts of the beach an alternate but oblique movement, which results in deposits of sand or gravel on the south side; the prevailing winds being from the north. When these substances reach the mouth of the Adour, they fall into the channel.

from which the ebb drives them towards the sea. The sand is transported to a distance, but the gravel stops at the point where the current, weakened by contact with the swell setting inwards from the sea, no longer possesses the force necessary to bear it away. But the bar formed by these accumulations, is attacked by the waves which carry off the upper deposits and throw them back upon one of the banks, according to the direction of the wind. In short, there exists a continual movement of sand and gravel, enlarging the bar at the expense of the beach, and vice versa. The waters of the Adour, confined between the jetties, cross the bar, attacking and hollowing it in a direction which varies according to circumstances. The furrow thus formed, constitutes the passage. The position and dimensions of this passage vary with the state of the sea and the volume of the river. With abundance of water and a smooth sea, the gravel forming the bar is driven out and the passage commences to enlarge itself; but with a small supply of water and a rough sea, the gravel is thrown back towards the river and the accumulations recommence.

With a view of confining and directing the current of the river, two dikes had been constructed in masonry, in the year 1740, with a space of 300 metres between them. From 1740 to 1838, these works were extended in such a manner as to narrow the bed of the river, in order to ensure the effect of the current upon the stoppage in the channel, and low jetties on piling, with stone packing, were added and made flush with the level of high neap-tide.

In 1838, the low southern jetty was 540 metres in length, and projected 300 metres beyond that of the north. The breadth of the river at the extremity of the northern jetty was 160 metres. The depth of water on the bar remained as before, and the only success achieved, was in throwing the bank and bar further back towards the sea, a distance nearly equivalent to the length of the solid jetties. The depth below the lowest tides varied between 1m,50 and 2 metres in ordinary circumstances; but with a succession of westerly gales and a scanty supply of water in the Adour, it diminished to less than 1 metre, while with a considerable volume of water, it was 3 metres at the most. To this depth must be added about 2m,20 at neap-tide and 3m,20 at ordinary spring-tide. However, the extension of the southern jetty beyond that of the north, had the effect of avoiding those great deviations towards the south, which rendered the entrance so dangerous, and the ensuing changes shifted the passage very slightly from a W. N. W. direction, which is considered by mariners the safest and most convenient.

In 1854 the surveys were resumed, and M. Daguenet, engineer of the port, proposed to apply the system of open jetties, suggested by M. Alfan de Riveira, director general of public works in the kingdom of Naples, as a means of improving the embouchures of rivers obstructed by sand.

A decree of the 29th May 1858, fixed the extent of the works to be executed, and allotted the sum of 1,690,000 fr. to the improvement of the mouth of the Adour. These works were to comprise : on the south, 200 metres of solid jetty or pier, and 200 metres of open jetty: and on the north, 666 metres of open jetty. The old and new jetties were besides to be covered with a flooring(1).

These works were finished by the end of 1861, including an extension of the open jetty, 100 metrés on each bank, which had been authorized by a ministerial decision of the 8th June of the same year. The open jetties consisted of a row of piles, 30 centimetres in diameter and 60 centimetres apart, bound by horizontal ties and stone packing, originally 4 metres below the lowest tide. But afterwards, in order to give more stability to the piling, this was increased to 2 metres below the lowest tide, while behind, two rows of piles farther apart, supported the principal row.

The solid jetty differs only in the fact that the stone packing in natural blocks is raised to the level of high neap-tide, both descriptions of jetty being brought to the same level. From their completion, the works, especially the service-bridge surmounting the jetties, had to encounter the violent storms of each winter, causing damages that were capable of being repaired. But during the winter of 1864-1865, a new destructive agency disclosed itself in alarming proportions. It was perceived that the piles of the open jetties were attacked by the teredo worm, in the lower part, commencing from the level of ebb-tide. In a comparatively short time the ravages of this insect assumed such magnitude, that it became necessary to abandon 115 metres of the open jetty at the extremity of the southern side, and 132 metres at the end of the northen side.

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(1) The southern jetty was intended to turn the current in the direction of the new jetties which were to be inclined 18° more to the north than the old ones.

Open iron jetties. — In 1866, the engineer of the port, M. Prompt, undertook the survey for the reconstruction of the jetties destroyed by the teredo, and proposed to replace the timber piling by cast iron tubes filled in with beton, and these plans were pursued with the assistance of the firm of Cail and Fives-Lille in participation. A decree of the 27th November 1868 authorised the reconstruction of the jetties on this system.

The plan comprises twenty one tubes or pillars on the south, and twenty four on the north side. These tubes are hollow cast iron cylinders, 2 metres in diameter, and are sunk into the bottom, $7^{m},30$ below the lowest tides, by means of compressed air. Towards the extremity of the jetty, and with a view of possible undermining or washing away of the soil, the sinking was carried to a depth of $11^{m},80$. The pillars, 5 metres apart from centre to centre, are filled with beton and surmounted by a cast iron capital with two flanges pierced with holes, in which are bolted the supports of the flooring or iron foot-bridge. The intervening spaces will be filled with stone packing, the upper plane of which will be regulated, following a slope of one centimetre per metre towards the sea, so that its level at the last pillar, may be 3 metrés below the lowest tides. Two sets of double longitudinal horizontal ties, at different heights, will extend from one pillar to another, and between these ties, wooden sluices were intended to slide at discretion. But experience does not appear to favour this plan, which would not resist the shocks of a heavy sea. Similarly to the old jetties, the tubes are made flush with the level of high neap-tides.

At the present date this undertaking is being actively proceeded with, and the southern side is finished, with the exception of the sluices, which will only be placed when their necessity shall be recognized.

Piers in stone packing with wooden foot-bridge. — Some parts of the old open jetties, higher up than those in iron, will be preserved on both banks, and piers are being established, 12^m,50 apart from centre to centre, formed of solid stone packing covered with a mass of beton as deep as the ebb-tide will permit. These piers, which, at the level of average tides, leave as many spaces as solid parts, will effectually replace the piles of the former jetties, which are disappearing under the action of the teredo and the waves. Barlow rails are let into the piers, and support the flooring of an American foot-bridge which serves as a platform for the materials. After the subsidence occasioned at first by the action of the floods and waves, these piers manifest great stability.

Nature of materials. — The stone packing employed in the works of the bar, comes from the quarries of ophite on the banks of the Nive. The minimum weight of the stones is 50 kilogrammes, and the average weight 100 kilogrammes.

The permanent flooring of the iron foot-bridge will be in oak.

That on the Barlow rails and the piers, is in pine from the Landes, but will be replaced by a frame bearing also an oak flooring.

Pile-driving carriage. — For setting and driving the tubes or pillars, a machine has been used called a *chariot* *de fonçage*, or pile-driving carriage, supplied by the firm of Cail and Fives-Lille, and of which the plan, elevation, and section are produced.

The elevation shows the carriage, supported on two pillars already driven, and in the act of setting the next one. The tubes intended to form this pillar are brought by trollies, raised by means of a winch surmounting the carriage, and deposited temporarily on a platform above the place they are destined to occupy. On this platform are collected a sufficient number of tubes, so that the trunk of the pillar, put in position by the winch, reaches above the level of ebb-tide. As many tubes as possible are added, the guide rods are fixed, and an air-chamber is placed above all, and put in communication with the compressing machine established at the end of the foot-bridge. This machine is connected with the chamber, by a long cast iron pipe resting on the floor of the bridge, and the operation of sinking commences. Under the pressure of 10,000 kilogrammes of pig-iron, which ballasts the chamber, the edge of the lower tube penetrates the soil to a depth which varies according to circumstances. Two men in the interior of the pillar, dig round the circumference and fill buckets which are raised and emptied by other men in the air-chamber. The pillar descends, and when it has attained the depth previously fixed, it is filled in with beton in rapidly hardening cement mortar, to prevent the water penetrating, and then with Portland cement. If the pillar is not high enough in the first instance, the air-chamber is taken off and a sufficient number of tubes are added, and for this purpose tubes of different lengths are provided.

When the sinking is finished, the air-chamber is replaced by an upper tube forming a capital. On this capital are put together the iron girders, which form rails for the carriage, and by the aid of pulleys, attached to the pillars already driven, the carriage is advanced 5 metres (the space intervening between the pillars), in order to set the next pillar.

If the operation is carried on in the natural soil, sand, or gravel, a pillar 8 metres in length can be driven in three days, filled in with beton in two days, and three more would suffice for placing the capital, and the girders, and to advance the driving carriage; in all, eight days. But the circumstances are altered when the remains of the former jetty are encountered in the soil. Not only it is necessary to dig through stone-work of ophite, so hard that a chisel is necessary to cut into it, but the edge of the pillar is frequently stopped by rails, bolts, and old piles that are with difficulty got rid off, by cutting, breaking and chopping, so that, on the average, it has taken eighteen days to sink each pillar.

Up to the present time, the cost has attained the sum of 660,150 francs, and the expenditure necessary to complete the works will be 289,850 francs. To this sum must be added 600,000 francs, in order to substitute throughout iron or masonry in lieu of pine, for the reconstruction of the service-bridges above the open jetties. The system of open jetties has already been the means of augmenting the depth of the channel, a result that the solid jetties failed to accomplish. These last formed a permanent sill, and caused both beach and bar to advance towards the open sea. Whereas, with the open jetties, the water forms numerous small lateral discharges, which prevent the sand from settling along the jetty, while the volume of water is confined and directed against the bar. This latter is not displaced, and the augmentation of depth already obtained, is 1 metre, and will be still more considerable, when the influence of the eighteen pillars which remain to be placed in position, on the northern side, adds to the rapidity of the current.

The works of the open jetties were planned and executed under the direction of MM. FLOUCAUD DE FOURCROY, PAIRIER and DAGUENET, engineers in chief, by MM. DAGUENET. PROMPT and STOECKLIN, resident engineers. The direction of the open jetties was confided to M. Ulysse PALAA, principal conducteur, till the 1st July 1863. The firm of CAIL and FIVES-LILLE, with M. PROMPT, engineer, has taken an active part in the preparation of the plans of the iron jetties. This firm supplied the material for setting and fixing the pillars till the early part of 1872, since which period. the superintendence of the works has been exclusively confided to M. RAMONBORDES, conducteur.

XXX

PORT OF SAINT-JEAN-DE-LUZ.

EMBANKMENT AT SOCOA AND MOLE AT THE ARTHA.

Drawings on scales varying from $0^{m},0\,002$ to $0^{m},20$.

The port of Saint-Jean-de-Luz consists of a bay or natural roadstead, and two small stranding ports; that of Saint-Jean-de-Luz is formed by the bed of the Nivelle, while that of Socoa was created at the entrance of the bay on the western side, by the construction of several dikes, arranged so as to shelter it from the waves.

The bay forms a kind of half-circle, open at the north 15° west; its entrance between the points of Socoa (west) and Sainte-Barbe (east), is 1,500 metres, and its width as far as the embouchure of the Nivelle, is 1,100 metres.

The depth of water is 13 metres below the lowest tide, and for a superficies of 70 hectares, the depth exceeds 6 metres, while for 20 hectares it is more than 10 metres. Winds from the north and west made the bay very rough, but two stone dikes are in course of construction to shelter it, one of which, commencing at Socoa, will be 335 metres in length, and the other, isolated in the sea, and established on the Artha rock, will be from 200 to 250 metres in length. These two works will have a passage between them 300 metres in length, and their completion will result not only in constituting Saint-Jean-de-Luz a port of refuge, but in saving the town from the destruction with which it is threatened, by the continuous encroachments of the sea. An embankment, called *threshold of security*, a section of which is given, and which is only a bank of sand faced, is the sole protection at the present moment (1).

In the roadstead and port of Socoa, the water rises 3m,30 at neap, and 4m,30 at spring-tides, above the level of the lowest ebb. But in the interior of the port of Saint-Jean-de-Luz, the difference is not so great, and the water only rises 3m,60 above its level at high spring-tides.

A decree of the 7th October 1863 ordered the construction of the western dike, and authorised an expenditure of 2 millions of francs to complete it for a length of 260 metres.

A decree of the 25th May 1867 authorised the additional works necessary for closing the roadstead, the estimate of which is 4,500,000 francs, comprising: the extension of the Socoa dike by a supplementary length of 75 metres, and the construction of a breakwater on the Artha rock, 200 to 250 metres in length; the passage between the two dikes, to be 300 metres at low water of the equinoctial spring-tide. These works are being proceeded with, and 285 metres of the Socoa dike are finished; the foundations are laid for the remaining length, and natural and artificial blocks are being sunk for the mole of the Artha.

The Socoa dike was executed first, in order to shelter the anchorage previously existing, in which there is a depth of 6 metres at low water.

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(1) In consequence of some modifications these figures differ from those of the plan of 1872.

At the same time, natural and artificial blocks were sunk to form the foundation of the Artha mole.

The manner in which these blocks are sunk, approaches as nearly as possible to the section type shown in the drawings. When the foundation reaches the level of low water, the surface is laid with natural blocks, and stones are set in the spaces. Then, taking advantage of the ebb-tide, successive courses of beton and rubble are laid over all. The stones are set edge-wise in the beton, so as to bind the following layer. But the commencement of the upper part of the stone-work is deferred, till the foundation has borne the test of two winters, and the shocks of heavy seas and violent gales, to such an extent that the subsidence of the blocks may be considered definitive.

The calcareous strata of an adjacent hill supply the natural blocks, the maximum weight of which is fixed at 2,000 kilogrammes, and the minimum at 500. From the same hill are obtained, the stone for the facings and body of the dike, and the stone broken to a size of $0^{m},10$ for the beton. The sand is taken from the beach.

The cement employed for the artificial blocks is from Portland in England, or from Boulogne-sur-Mer. For the wall-work executed during low tide, a rapidly hardening cement is used, which comes from the Gurrutchaga works, Zumaya in Spain, or Cahors in France.

The concave form given to the facing of the side exposed to the action of the sea, modifies the shocks, and diminishes the pressure against the dike, by causing the wave to glide upwards, till it acquires a vertical direction, when it falls back upon itself. But in the return, there follows an action which has a tendency to displace the foundation blocks at the foot of the wall, and the knowledge of this fact may suggest the expediency of constructing the wall of the Artha mole without the concavity, and with a slight diminution.

A temporary railway has been established at the foot of the hill, along the front of the quarry. It crosses the Ounxin on a wooden bridge formed with American lattice girders. By means of an embankment, it then traverses the swampy plain on the left bank, and passing by the yard where the artificial blocks are made, and between the houses of Socoa and the parapet of the quay wall, it goes to the entrance of the stranding port, by the aid of a viaduct with stone piers and wooden frame in American trellis girders. Afterwards, it is carried along the old embankment of Socoa, and is extended along the new dike in proportion to the requirements of the work.

Where it quits the plain of the Ounxin, and near the stone bridge on the Socoa road, a branch line is established, which goes to the sand down, and supplies the works with sand. At the entrance to the port of Socoa, two more branches are formed, one of which follows the southern embankment of the stranding port, while the other terminates at the top of the inclined plane arranged to facilitate the embarkation of the artificial blocks, which will be spoken of shortly. This railway is served by two locomotive engines of 35 and 60 horse power, also with the number of trucks necessary for the conveyance of the various materials. Another branch crosses the timber yard. A weighing machine is established under the principal line, to weigh the trucks loaded with natural blocks, quarry, and broken stone, the contractor for these materials being paid according to the weight.

This railway serves the quarry and sand down, whence it takes materials to the spot, either for the fabrication of the blocks or for the wall masonry. The southern embankment branch permits the trucks loaded with blocks, to come under a fixed crane carrying a movable winch, which embarks them in the pontoons. By the aid of a steam-crane, vessels bringing cement can unload, and the barrels and sacks of cement are conveyed by the railway, either to the storehouses along the line, or to the shed of the great work yard.

Lastly, the railway facilitates the propulsion of the great stone trucks by the locomotives, and the artificial blocks are thus taken to the summit of the inclined plane that conveys them to the pontoon.

Work yards. — The beton blocks are first made in wooden boxes or moulds, in the port itself, and the mortar on the embankments round the port, or on a wooden scaffolding, with a screw worked by a portable engine. When mixed with the broken stone, by the aid of rakes and shovels, the beton is thrown into a wooden trough from which it is run into a mould, and compressed by stampers. The blocks are made during low water, and are entirely finished during one tide. The pontoons come and hook them on, for the purpose of submersion, but can only take one block each, during a tide, and the yard will not contain more than eighty blocks. To communicate greater activity to the works, a second and more extensive work-yard has been established, capable of containing five hundred blocks above the tide mark. The yard is connected with the port of Socoa by an extension of the railway which crosses it, and by the inclined plane. Near one end of this work yard is a shed, surmounting a terrace, under which is established a storehouse for the cement. This building is supplied by a branch line of railway which brings the cement, sand, and broken stone, for mixing the beton. The terrace under the shed is at the necessary height above the moulds, and allows the beton to be brought in trollies along the iron rails resting on the blocks of beton already made.

Cranes. — A movable hand-crane with a sweep of 6 metres, is used at the quarry, to load the blocks on the trucks. On the northern embankment a steam-crane (Chretien's system) is established, which discharges with great rapidity the vessels bringing cement, and is also employed to lift the natural blocks from the trucks, on to the pontoons employed to sink them. A wooden crane, drawings of which are produced, serves to raise the blocks in the great work yard and to convey them, travelling on Barlow rails, as far as the stone trucks made expressly to receive them, and they are then propelled by a locomotive up to the top of the inclined plane. This crane carries at each of its four corners a jack-screw, by the aid of which the blocks are raised. These jack-screws are moved by levers acting on a lantern-wheel which carries two ratchets, one of the faces of which is vertical, the other rounded, so that the lever acts with an alternate motion, without obliging the men to leave the top of the block.

Inclined plane. — Arrived at the top of the inclined plane, the truck carrying the block is hooked on to a cable which forms the running end of a tackle with six sheaves, placed vertically in a frame 15 metres in height. The movable pulley carries a counter-poise, which rises as the truck descends the inclined plane. The counter-poise causes the empty truck to ascend, as soon the pontoon has received the block. In the descent, the difference between the traction strain and the resistance of the counter-poise, is regulated by a screw brake acting on a cast iron drum, round which the cable winds. The inclined plane is 90 metres in length, and its slope varies from 55 to 80 millimetres per metre, so as to equalise the traction strain exercised by the block in its descent, whatever may be the lightening effect produced by its gradual immersion in the water.

Naval material. — Two pontoons, connected by side-beams, are generally employed for sinking the blocks (see drawings). A space of 3 metres is left between them, and they are connected by strong balks of timber, to which the block is suspended by a hook with a trigger, details of which are given in the drawings.

But when it is a question of placing the blocks at the foot of the wall, in order to approach it with greater facility, a large pontoon is employed, which carries the block at one end, and is ballasted at the other, in such a manner as to preserve the line of flotation, when the pontoon is loaded.

For sinking the natural blocks, bridged boats were used, and the blocks were placed on the bridge, which inclines sufficiently from each side of the longitudinal axis of the boat, and is retained there by the doors, which are lowered when the boat arrives at its destination.

At the present time, a boat completely bridged is employed, in the centre of which is an opening 5 metres by 2 metres. The bottom of this aperture is formed of two gratings in Barlow rails, placed on two horizontal axes. The natural blocks, resting on the gratings, are plunged into the water during the voyage, and on their arrival at the place of sinking, the fastenings are let go, the gratings turn on their axes, and the load is immediately submerged.

Two steam launches, respectively 18^{m},20 and 18^{m},80 in length, 2^{m},75 and 4 metres in breadth in the middle, tow the pontoons, loaded with the blocks, to the spot where the they are to be sunk. The first steamer has an engine of 6, the second, one of 12 horse power.

The way to the place for sinking either the natural or artificial blocks, is indicated by beacons placed along the coast.

Artificial blocks. — The cubic measurement of all the blocks is 20 cubic metres, length 4 metres, breadth 2^{m},50 and depth 2 metres. Those made in the port, are in beton, and are composed of 2 of stones and 1 of mortar; the mortar consists of one part in volume of Portland cement and 2 $\frac{1}{4}$ of sand.

In the great work-yard, along the principal line of railway, blocks of rubble masonry have been constructed with mortar of Portland cement, in which the volume of sand was increased to 3. An attempt has even been made to construct some blocks with 3 $\frac{1}{4}$ of sand. The blocks of the port are sunk at the expiration of two months, but the extent of the great yard allows them to be left to dry for a longer space of time, and that is why the proportion of sand has been increased. In forming the block, two ties of iron wire are embedded therein, and connected at the lower part by a piece of wood, in such a manner that a solidarity is imparted to the whole block from the two points of suspension. The upper ends are fitted with rings, which hook on to the claws at the end of the jack-screws of the crane in the great yard, or to the pontoon hooks. As a measure of precaution, the blocks are generally secured by one or two iron chains, the ends of which are fastened to the pontoons.

The engineers that drew the plans and, up to the present time, have directed the execution of the works, are:

MM. **Floucaud de Fourcroy**, **Pairier** and **Daguenet**, engineers in chief;

MM. **Daguenet**, **Prompt**, **Stoecklin** and **André**, resident engineers.

Amongst the conducteurs that have seconded the engineers, ought to be mentioned: M. **Lichebo**, principal conducteur till the 1st March 1872, and M. **Millon**, *conducteur embrigadé*, since that date.

XXXI

PORT OF MARSEILLE.

1. EXTENSION OF BASINS.

2. GRAVING DOCKS.

3. BRIDGE, EITHER DRAW-BRIDGE OR SWING-BRIDGE AT DISCRETION.

Drawings on scales varying from $0^{m},0001$ to $0^{m},05$.
A model on a scale of $0^{m},0025$.

1. EXTENSION OF BASINS.

The port of Marseille, which in 1844 only possessed its old natural harbour, with a superficies of 29 hectares and 2,700 metres of quay, comprises, at the present time, a series of exterior basins all reclaimed from the sea, and presenting a surface of water perfectly sheltered, of 136 hectares, a development of quays of 12,600 metres, 8,500 of which can be utilised for the purposes of loading and discharging cargo. Around the basins, vast warehouses have been erected, capable of receiving 130,000 tons of goods. Large spaces of ground, adjacent to the basins, augment the importance of the warehouses, and lastly, five graving docks afford all necessary facilities for the examination and repair of vessels of every class. One of these docks, $141^{m},50$ in length, is under certain conditions adequate to the reception of the largest vessels, and the *Great Eastern,* 200 metres in length, could enter the port without inconvenience. Twenty thousand vessels, of 5,000,000 tons measurement, enter and leave the port of Marseille during the course of the year.

At the completion of the works now in course of construction, and which will be finished in five years, the total development of the quays will attain a length of 17,200 metres, 12,500 of which will be available for the operations of loading and discharging cargo.

The depth of water varies in the different basins. In the old basin, it is from 6 to 7 metres below low tides, while the new basins have, a few places excepted, a minimum depth of 7 metres, and for an extent of more than 50 hectares, the depth exceeds 9 metres. Along the exterior dike, of which the total length at the present day is 3,070 metres, the depth of water ranges successively from 11 to 15 and 20 metres.

There are three passages, with a depth of water as follows. That of the old port, $7^m,50$ below the lowest tides; the southern passage of the new basins, 9 metres, and the northern passage, 15 metres.

In the elaboration of the plans of the exterior basins, the prominent feature consists in the formation, along the shore, of a series of basins separated from each other by interior moles or causeways, with strong foundations, protected on the side next the sea, by a dike parallel to the coast, and leaving, between it and the ends of the moles, a channel sufficiently large to permit of easy communication between all these basins. This plan allows the capacity of the port to be always proportioned to the increasing requirements of commerce. by adding new moles in succession to those existing, and protecting them by a corresponding extension of the exterior dike.

The sums expended upon the port of Marseille, not including the warehouses, amount since 1844, the period at which the new basins were commenced, to 50 millions, and this total will be augmented to 70 millions, after the completion of the works in course of construction.

SYSTEM OF CONSTRUCTION.

Exterior dike. — The exterior dike of the port of Marseille is formed of natural and artificial blocks.

Several important works of a similar nature were in existence at the time when this dike was projected. There were the breakwaters of Cherbourg in France, and Plymouth in England, and others were being actively carried on, viz. the mole of Algiers, and the breakwater of the Delaware, in the United States; and finally, the Holyhead breakwater, a work of great importance, was under consideration nearly at the same time as that of Marseille.

The principal idea by which the projectors of the great breakwaters of Cherbourg, Plymouth, Holyhead and Delaware appear to have been actuated, is that of employing simultaneously vast quantities of stone from the adjacent quarries, and leaving to the sea the care of forming the slope or talus intended to be permanent.

In addition to this paramount idea, another suggested itself, viz. that of reserving the large material to cover the exterior talus of the mass forming the main body of the work. Thus at Cherbourg, a course of large blocks, 1^m,25 in average thickness, was deposited on the talus and sunk to nearly 5 metres below the lowest water mark, beyond which limit, in that locality, the powerful action of the waves does not extend.

Nevertheless, in the parts of the breakwater most exposed to the action of the waves, and in those that it imports particularly to protect from injury, these blocks do not appear to afford sufficient security, and in their turn they are being covered by artificial blocks of 20 cubic metres.

Thus at Plymouth, the exterior talus is pitched with blocks 80 centimetres in thickness by 1^m,20 in length and 1 metre in breadth, joined by Parker cement.

At the Delaware, for the defence of the talus, blocks of 4,000 to 5,000 kilogrammes are employed, and set regularly as bonders.

A similar method prevails at Holyhead.

The mole at Algiers is planned upon a system totally different. The projector believed it imperative to use only blocks of such dimensions as would preclude the possibility of displacement by the waves. And this appeared to him an idea well-founded, seeing that the action of the wave is in proportion to the surface struck, while the resistance of the block increases as its cube. The work was therefore accomplished by means of artificial blocks, first of 10 and afterwards of 15 cubic metres.

In the breakwaters of Cherbourg, Plymouth, Holyhead, and the Delaware, the exterior talus varied according to the position of the work, between 5 and 10 for one, within the zone of action of the waves, an action which had an appreciable effect at nearly 5 metres below the lowest tide, but experience has demonstrated that the talus of the mole at Algiers preserves an inclination of about $1\frac{1}{4}$ for 1.

The dike at Marseille has been constructed upon a system embodying the combined experience of Cherbourg and Algiers. On the one hand, the idea of directly opposing the powerful action of the waves by enormous blocks, artificially constructed, has been taken from the mole at Algiers, while on the other, the breakwater at Cherbourg suggested the employment of natural blocks of all dimensions, to constitute the main body of the work. The former serves as a facing to the latter, and both have been used simultaneously, in such a manner as not to leave the natural blocks exposed to the great force of the waves. As this force sensibly diminishes, at a depth of 5 metres below ebb-tides, the use of artificial blocks has been limited to 6 metres below that level.

With the twofold view of solidity and economy, positions have been assigned to the natural blocks, according to their respective dimensions. This course has been adopted in preference to the plan followed in the construction of the works already mentioned, in which the stone was used indiscriminately as it came from the quarry. From considerations of economy, the small materials have not been mixed with the large, in order to preserve the greatest possible void. With a view to solidity, the large blocks have been so disposed as to entirely surround the small ones.

Experience has fully confirmed the rationale of these ideas. That part of the dike which protects the basin of la Joliette, was commenced 27 years ago; and that which shelters the basin of the marine terminus dates from 16 years, while it is one year since that of the National basin was completed. Now all these parts of the dike are, at the present time, in an excellent state of preservation. If then, at the inauguration of this system 25 years ago, some reserve was necessary in expressing an opinion upon its efficiency, and that the never failing test of time could alone pronounce a reliable verdict, upon its efficiency, this can no longer be the case to day. Time has satisfactorily demonstrated the excellence of this system, which cannot fail to be generally adopted by reason of its remarkable economy.

Interior moles. — The interior moles are formed by means of quay walls, which constitute the outer part, and are filled in with ordinary earth, brought to the enclosure thus prepared.

The quay walls rest on a sub-marine foundation of natural blocks, with an upper course of artificial ones. These are laid dry in perpends, with breaking joints, to a depth of 6 metres below the lowest tides. In the works now constructing, this depth has been increased to 7 metres.

The system of artificial blocks, superposed without mortar, is perfectly adapted to all works constructed upon ground of a precarious or moving nature, such as submarine walls, if recently built.

2. GRAVING DOCKS.

The graving docks occupy a rectangular space of ground, 745 metres in length by 280 metres in width, at the east of the National basin and parallel to it.

They comprise at the present time:

1. A basin for repairing vessels while afloat, forming also an outer basin, 360 metres in length by 160 metres in width, and with a depth of water of 8 metres.

2. Four dry or graving docks in masonry, completely terminated, and two new ones commenced.

3. A canal, 28 metres in width by 92 in length and 8 metres in depth, connects the repairing basin with the National basin.

4. The ground necessary for the establishment of work shops, and for increasing the number of dry docks to eleven.

Up to the present time those finished are:

N° 1, the largest dock, 141^m,50, in length with a depth of water of 7 metres below ebb-tides.

N° 2, 110 metres in length with 6 metres of water.

N^{os} 3 and 4, 90 metres in length with 6 metres of water.

The longitudinal gradient of these docks is 0^m,01 per metre.

All the works of the repairing docks have been executed dry, by the aid of a coffer-dam in beton, 1,218 metres in length. This dam was established on a bottom of rock or hard clay, varying from 0 to 11 metres.

The gates which close these docks consist of an iron water-tight caisson which can be floated or grounded, without the assistance of pumps, by the simple process of regulating the quantity of water which serves for ballast.

The machinery for pumping out consists of four separate steam engines, working four centrifugal pumps which, when in action together, are capable of elevating ten thousand cubic metres of water per hour, to a height of $4^{m},50$.

This power, much in excess of actual requirements, has been established in view of an augmentation in the number of docks, which, as before stated, can be increased to eleven.

The entrance of these docks is 28 metres in width, and is crossed by an iron swing-bridge of one bay, 62 metres in length by $15^{m},94$ in breadth, having a single line of railway, a road for vehicles and an outside foot-bridge for pedestrians. This bridge is one of the largest ever constructed, of its kind.

The weight of the movable part is 700 tons, and the rotation is effected upon two friction rollers and a central pivot, raised by a water pressure of 270 atmospheres.

When working, the bridge is supported at its extremity by three forged iron rollers which permit expansion. At the end of the breech it bears on three conical wedges, worked simultaneously by a connecting bar; lastly, on a cross-beam resting on stone blocks.

The opening of the bridge gives rise to three operations:

1. Wedging up the end of the breech; 2. raising the bridge till the supports at the extremity are completely disengaged; 3. rotation. These three operations require 2 minutes 58 seconds. The closing of the bridge is effected by three operations, reversing those preceding, and is accomplished in 3 minutes.

Whatever may be the force of the wind, one man suffices to perform these manœuvres, and the wind is sufficiently strong sometimes at Marseille, to delay the departure of vessels.

This bridge rests on stone-work, $9^m,50$ in diameter, founded on hard clay, at a depth of $8^m,30$ below ebb-tides.

The docks for the repair and inspection of vessels have cost 8,000,000 francs.

3. BRIDGE, EITHER DRAW-BRIDGE OR SWING-BRIDGE AT DISCRETION.

This bridge is established on the passage of the Joliette, which is $21^m,30$ in breadth. It has a double action: one of rotation, as in most movable bridges; the other of raising the flap (volée). This arrangement was judged expedient from the following considerations.

The daily maritime circulation through la Joliette passage consists of about ten masted vessels and forty barges or lighters. The complete rotation of the bridge is required for the vessels, but the passage of the barges is effected by partially raising it, which is accomplished in less time than the rotation. By this double arrangement, much time is saved in the successive interruptions of the traffic on the bridge. The total diminution of time in the interruptions is 4 hours in a day of 10 hours work.

The length of the iron bay of the bridge is $41^m,09$, and its breadth is 8 metres, comprising a line of rails, a carriage way, and two foot-ways.

When the bridge is closed, it rests on fixed blocks placed in four points of its length, also on the tops of the two quays of the passage, under the cross-beam and the second upright of the breech. In this position, the friction rollers are separated from the circular rail, on which they turn, by a space of 3 centimetres.

The manœuvres are accomplished by means of a water pressure of 52 atmospheres, effected in the accumulators of the Dock Company.

The water is introduced into a vertical hydraulic press, the piston of which, placed a little out of the centre of gravity of the flooring, in relation to the breech, assists in raising the bridge, and also serves as a pivot for its rotation.

When the piston rises, the bridge being raised, turns round in the horizontal direction, by the aid of the breech friction rollers, until these latter have descended sufficiently to bear upon the rail. From this moment it is the horizontal hinge of the flooring which forms the new support, and detaches itself from the nearest blocks, as it had previously detached itself from the others.

For the rotation, the rising of the pivot is arrested at 20 centimetres. For raising the bridge completely, it can be elevated to 90 centimetres. The gradient of the flooring is then 68 millimetres per metre, and the clear height between the average water level and the bottom of the flap or fly (volée) is $4^m,60$ at its extremity, while the height at the lower end is only $1^m,80$.

The diameter of the piston is $0^m,85$ and its length 2 metres, so that when it rises to the full extent, there is still a length of $1^m,10$ in the press.

All the manœuvres are executed with the greatest facility, by one man at the engine, and from a place close to his lodging, he can manage the working of the bridge.

The weight of this bridge is 300 tons, and it rests on a stone pier 6 metres in diameter, founded on the rock, by means of a caisson with compressed air, at a depth of 14 metres below ebb-tides.

The total outlay was	316,000 fr.
For the bay, not including the masonry of the approaches	250,000 fr.
For the foundation pier	66,000
Total	316,000 fr.

The great works of the port of Marseille date principally from 1844. From that period till 1857 they were successively directed by MM. Toussaint, Bergis, Montet and de Montricher, engineers in chief, and by M. Pascal, resident engineer. Since 1857 they have been directed by M. Pascal, engineer in chief, and MM. André, Bernard and Denamiel, resident engineers.

Among the conducteurs that have seconded the engineers, mention should be made of MM. Bullier, Lévens, Coignard, Sébillotte, Pissère and Bénézeth.

The contractors have been MM. Dussand brothers, Barthelon, Rabattu, Vaccaro and Michel (Désiré).

The floating gates, the pumping machinery and the swing-bridge were planned by M. Barret, engineer to the Dock Company, and executed by the New Society of Forges and Workshops of the Mediterranean, under the direction of this engineer.

XXXI

SAINT-LOUIS CANAL.

IMPROVEMENT OF THE EMBOUCHURES OF THE RHONE.

Drawings on scales varying from $0^{m},00\,002$ to $0^{m},05$.

Numerous attempts have been made to lower the bar of the Rhone, where this river discharges its waters into the Mediterranean, but hitherto they have resulted in failure. It was therefore decided to open a direct communication between the gulf of Foz and the deep part of the river, above the bar, by means of a canal designated the Saint-Louis Canal.

This canal begins on the left bank of the Rhone, at the commencement of the dike constructed in 1856 for the embankment of the Bras de l'Est (Eastern Arm), at a distance of 600 metres below the Tour Saint-Louis, and taking a straight line from west to east, it terminates in the gulf of Foz, opposite the port of Boue. At the Rhone end, it is closed by a lock, while at the sea, it discharges into a port formed by two jetties. On the canal side of the lock, a basin has been excavated to enable vessels to turn round, in order to pass from the lock into the canal, and vice versa.

The Saint-Louis canal having been established as a substitute for the natural embouchure of the Rhone, it was unnecessary to create a depth of water exceeding that of the river itself, below the port of Arles. Between Arles and Saint-Louis, the depth of water is scarcely 2 metres, and even with the improvements now being made, it does not appear probable that more than 4 metres will ever be obtained, in consequence of the reefs of hard pudding stone, encountered at certain points in the bed of the river. A depth of 4 metres was therefore considered sufficient for the mouth of the canal. But the idea presented itself that, the entrance of the Rhone once rendered practicable, the river traffic would immediately take such a development that it would be absolutely necessary to secure the possibility of putting it into communication with the maritime navigation. For this reason, the Government decided to give a depth of 5 metres to the Saint-Louis canal. For a maritime channel of such dimensions, it was essential to create a port on the Rhone, capable of receiving vessels coming from the sea by the canal. This port was formed at Saint-Louis itself; the basin was enlarged sufficiently to admit of the necessary manœuvres of vessels: quays were built, and at the present moment, others are in course of construction on the Rhone, just above the outlet of the canal.

The canal, properly so called, is 3,330 metres in length from its entrance into the basin at one end to the sea shore at the other.

It is 6 metres in depth below the level of low tides.

The width at the bottom is 30 metres, and at the level of low tides 63 metres. The banks are protected to a height of $1^{m},30$, above low water mark in the canal proper, by dry stone pitching, $0^{m},40$ in thickness with a slope of

45°, and at the crossing of the basin to a level of 1^{m},50. The pitching only descends 2 metres, and rests on a bench 6^{m},50 in width, and from this bench the bank is cut in talus, 2 in base to 1 in perpendicular.

On each side of the canal a towing path has been formed, 12 metres in breadth, with a level of 2 metres above the water.

Along the whole length of the towing paths, the earth excavated from the canal was put in depots or spoil-banks, and these have been kept 2^{m},50 above water level in such a manner as to be above the highest level of the waters of the Rhone, and to protect the canal in case of inundation.

The basin is 400 metres in length by 300 in width.

Quay walls have been built on three sides, and the length finished up to the present time is 850 metres. This length will attain 1,100 metres, when the walls in course of construction are terminated on the western, northern and eastern sides. The capping of the quays is established 2^{m},50 above water level and the earth platforms behind are made flush to the same height.

The works of the canal and basin were executed dry, by the aid of two coffer-dams, one at the sea end, the other in the excavations for the lock. A third coffer-dam was formed about half way between the two, in order to provide against the contingency of either of the end dams giving way. They were made partly with the natural soil, and partly with the clayey ground taken from the cuttings.

The draining was accomplished by means of rotary pumps (Neut and Dumont), worked by a portable engine.

There was a pumping shaft for each of the divisions, into which the canal and basin were separated by the centre coffer-dam, in which last, auxiliary pumping machinery was established. Each shaft was furnished with two rotary pumps, and two portable engines of 8 to 10 horse power.

The port is formed by two jetties, of which the southern one is parallel to the axis of the canal, at a distance of 48^{m},25 from the axis; it advances as far as the natural bottom of 6^{m},50, and is 1,746^{m},20 in length. The other commences 1,350 metres to the north of the canal; it has only advanced as far as the natural bottom of 3^{m},25, and is at present but 500 metres in length. Being perpendicular to the direction of the bank, it tends towards the wing wall of the northern jetty in such a manner, that if the two jetties should be carried out in a straight line as far as 7^{m},50, there would remain a passage 200 metres in width between the wing walls.

The jetties are constructed exclusively of rough stone, or the natural rock.

The northern jetty is only 1^{m},25, above the level of low tides, and is 4 metres broad at the top. It is built of stones of an average weight of 50 kilogrammes, and the talus are faced with stones of 300 kilogrammes.

The southern jetty is elevated 2^{m},50 above the water level, it has 0^{m},20 more convexity, and its breadth at the top is 2 metres. It is formed of stones of 50 kilogrammes, average weight. The facing of the northern talus is of stones of 300 kilogrammes, and that of the southern side. of blocks weighing at least 500 kilogrammes. For the wing wall, terminating the southern jetty, and which is about

20 metres in diameter at the top, the facing is composed of blocks of 1,200 kilogrammes in weight.

Above the level of low tides, the rough stone-work that forms the facing, has been carefully laid by hand, and tightened by stone splinters in form of wedges. At the level of the water, on each side of the southern jetty, a course of large stones and blocks has been laid, to prevent the slipping of the lower part of the talus, and the facings are thus kept in repair from the top of the jetty.

The inclination of the talus is 2 of base for 1 of height.

The works of the canal, commenced in 1864, were only terminated at the end of 1873.

The lock will give passage to vessels requiring to enter the Rhone from the sea, and also to boats coming from the Rhone to the canal. The dimensions have been calculated as follows :

Width between side walls	22^{m},00
Depth of water in centre at low tide	7 ,50
Working length of chamber	160 ,00
Total length of the work	184 ,50
Depth of water on sill	7 ,50
The depth of water in the canal is	6 ,00

The lock is inclined down stream from the river on an angle of 14° 2′ 10″.

It is provided with two pairs of gates, and the versed sine of the sills is one sixth of the breadth of the lock.

The side walls are perpendicular. The invert is laid to an arc of 2 metres versed sine, and the flooring of the gate chambers is 3 metres below the level of low tides, or 0^{m},50 below the lowest point of the invert. The gate recesses are 12^{m},60 in length by 0^{m},85 in depth.

Culverts are contrived in the side walls, and serve to fill and empty the chamber. These culverts are 1^{m},25 in breadth by 2 metres in height at their outlets in the recesses of the gate chambers, and the sills are horizontal and 5^{m},50 below water level, or at the level with the springing of the curve of the invert.

The heads of the lock, the side walls of the chamber, and the wing walls, are founded on piling, while the invert is laid directly on the soil.

Pine piles stripped of the bark were used; their average diameter was 0^{m},30 by a length of 12 metres, and the distance from centre to centre 1^{m},15. They were covered, without framing, by a mass of beton 1^{m},50 in thickness for the heads of the lock and the retaining walls, and by a thickness of 1 metre only, for the side walls of the chamber. The piles penetrate the beton 1 metre under the heads and 0^{m},50 under the side walls of the chamber, so that the layer of beton is 0^{m},50 in thickness throughout, above the plane of the cutting of the piles.

The eastern quay wall of the channel entering the Rhone is founded, like those of the basin, directly on the soil.

The western quay wall, the wing wall of the lock, and the quay of the Rhone, are constructed of solid masses of beton run into the enclosure.

The lock and its retaining walls, and the eastern quay wall of the channel, were built entirely dry, by means of a coffer-dam formed by the natural ground left intact along the Rhone, with a breadth of a few metres. A similar dam separated the excavations of the lock from those of the basin, so that in case of accident or rupture of the Rhone coffer-dam, the basin would be protected from the water.

The execution of the earth-works and masonry presented nothing worthy of remark. The piles were driven in by six pile-driving machines, and the monkey, weighing 800 kilogrammes, was raised by a steam winch. Each of the machines was able to drive 15 piles in a day, and being 12 metres in length, they were driven home. A series of 10 blows and a fall of 2 metres hardly caused a downward movement of $0^{m},10$.

The works of the lock were terminated in June 1873.

The gates are in rolled iron.

Each leaf is $11^{m},627$ in breadth, $9^{m},50$ in height and $0^{m},666$ in thickness, and consists of eleven horizontal beams or cross-pieces, identical, at equal distances apart, and joined at their extremities by two vertical beams or uprights, the heel-post and the mitre-post. The cross-pieces are formed of a web in sheet-iron $0^{m},010$ and two angle-irons $\frac{70 \times 70}{10}$. The uprights are made in the same manner. To the frame formed by the assemblage of these pieces, a continuous sheet-iron skin is added on both sides. Each leaf thus forms a rectangular chest, the bulk of which is such, that the weight of water which it displaces, is greater than the weight of the chest itself.

The middle part of this chest, which is below the level of the water, is arranged in such a manner as to form a float, in order to reduce the weight on the pivots and lessen the strain on the hinges. On the upper side of the gate, above and below the floating part, man-holes are provided, by means of which the water penetrates freely and the leaf floats always in the same conditions, whatever may be the depth of the upper or head water. The interior is accessible by the man-holes.

Each leaf is furnished with a pump, which serves to clear the water from the interior of the float.

The man-holes can be closed, and the compartments pumped dry, above and below the float; the gate then floats entirely, thus facilitating inspection and repair.

The thickness of the gates is the same throughout, while the breadth of the cross-braces varies with the thickness of the lining.

They bear against the sill through an oaken frame bolted to the frame-work of the gate itself. The mitre posts are in oak.

A wooden grating is bolted to the down-stream side of the gates, to protect them from the vessels passing through.

Lastly, the gates are surmounted by foot-bridges, the hand rail of which can be lowered, during the passage of a vessel through the lock. By this arrangement all damage from the rail is avoided.

The wrought and sheet-iron employed in the construction were carefully tested. They resisted, without breaking, a strain of 34 kilogrammes per square millimetre of section, in the direction perpendicular to the lamination.

Bessemer steel was selected for the sockets, pivots, gudgeons, and knees. This steel gave to a traction strain, a resistance of 68 kilogrammes, with an elongation of 16 per cent.

The gates were put together on the spot, exactly in the place they were to occupy, and this operation was effected before the water was admitted into the canal.

The weight of a gate, with the wood, is 49 tons, but in the water, owing to the action of the floating part, it is not more than 7,000 kilogrammes.

All the work, executed dry, was finished in March 1871.

On the 17th April 1871, the water was admitted, and on the 4th May following, the coffer-dams of the Rhone and the sea ends were opened.

At the last moment before letting in the water, the coffer-dams at the middle of the canal, and between the basin and the lock were removed; the coffer-dams at the extremities were taken away by means of steam dredges.

The insubmersible embankments on the left bank of the Rhone, formerly terminated 4 kilometres above Saint-Louis, so that, during floods, the Rhone overflowed the low lands along the northern side of the canal Saint-Louis, and discharged the water near the port. To obviate this inconvenience, it was necessary to suppplement the works of the canal by an insubmersible embankment, 4 kilometres in length, to connect the existing embankment with the banks of the canal Saint-Louis.

This work, known under the designation of the embankment of Eysselle, was completed in the month of December 1873.

The cost of the canal and port of Saint-Louis, including the supplementary works, will amount to 15,400,000 fr. divided as follows:

1. Canal, basin and port...............	10,053,000^{f},00^{c}
2. Lock............................	3,741,649 74
3. Lock-gates........................	174,496 74
4. Beacon of South jetty................	23,900 00
5. Embankment of Eysselle..............	25,742 98
6. Quays on the Rhone................	684,206 13
7. General expenses (about).............	697,004 41
	15,400,000^{f},00^{c}

The plans of the canal of Saint-Louis were drawn, and the works executed, under the direction of M. Pascal, engineer in chief of the special maritime service of the Mouths of the Rhone.

MM. Bernard and Guérard, engineers «des Ponts et Chaussées», were charged with the execution of the works.

M. Reybert, «conducteur des Ponts et Chaussées», has remained constantly attached to the surveys and the works of the embouchures and of the canal of Saint-Louis, since 1846.

XXXIII

ATLAS OF THE PORTS OF FRANCE.

Two portfolios of plans and maps.
Two volumes of notices.
The maps on a scale of 0^{m},0 000 075; the plans on a scale of 0^{m},0 002.

A ministerial decision of the 24th October 1868 ordered the publication of an atlas of the commercial ports of France, and appointed a commission to arrange the preliminaries and direct the execution of the work.

In addition to plans of all the ports, the atlas contains maps, at the same time hydrographic and territorial, intended to show the coast lines of our principal maritime establishments, as also their means of communication with the interior of the country. These maps and plans are accompanied by notices, furnishing the most essential and important information relative to the respective approaches, nautical conditions, successive development, present state and statistics of these ports.

The part published comprises the ports of the departments of the Nord, the Pas-de-Calais, the Somme, the Seine-Inférieure, the Eure, the Calvados, and the Manche, as far as Granville. The text constitutes the first two volumes of the notices.

The president of the commission is M. Reynaud, inspector general «des Ponts et Chaussées». At the commencement of the work, M. baron Baude was the secretary to the commission, but being carried off by a premature death, he was succeeded by M. de Dartein, engineer. Another engineer, M. E. Collignon, has been appointed secretary to the commission, and is charged with the direction of everything relating to the printing of the notices.

Chief draughtsman, M. Huguenin.

Engravers of the maps and plans, MM. Dulos and Perot.

FIFTH SECTION.

LIGHTHOUSES AND BEACONS.

XXXIV

STATE OF LIGHTS AND BEACONS

ON THE COASTS OF FRANCE.

A large volume in-8° with map.

These documents show the condition of lighthouses and beacons on the coasts of France, on the 1st January 1876.

At this date there were 379 lighthouses, not including those of Algeria, and this number was classified in the following manner:

Lighthouses	of the 1st order	45
	2nd order	6
	3rd order	31
	4th order	33
	5th order	254
Floating lights		10

290 lighthouses have been constructed or renewed, since the commencement of 1848.

Up to that period, the establishment of maritime beacons had not been seriously undertaken.

XXXV

LIGHTHOUSE OF CAPE SPARTEL.

(MOROCCO.)

Drawing on a scale of 0^m,04 (one twenty-fifth).

The vicinity of cape Spartel, which is situated on the south of the strait of Gibraltar, had been the scene of numerous disasters, when, in 1852, M. Jagerschmidt, the director of our consulate at Tangier, proposed to erect a lighthouse on this point. Some difficulty appeared to attend a proposition of this nature, seeing that the government of Morocco possesses no shipping, and consequently could not be actuated by any motives of interest in such an undertaking. There was also reason to believe that, up to a certain point, it would be disposed to take an unfavourable view of a project which, if successfully carried out, would deprive its subjects of the dishonest but considerable profit realised from the wrecks of unfortunate vessels driven upon their coasts. It was therefore considered indispensable to obtain the concurrence of the European powers most interested in the question, in order to surmount the opposition anticipated, as well as to contribute the sums necessary to defray the cost of the project, and subsequently to secure the proper maintenance of the light.

The idea was submitted to the Lighthouse Commission, by the members of which it was cordially received and energetically advocated. Unfortunately, obstacles interposed to disturb the preliminary accord necessary at the outset of the enterprise, and success appeared doubtful, if not impossible, when in 1860, the Brazilian frigate *Dona Isabel* was driven upon the cape and totally wrecked. This vessel was manned by a numerous crew, including pupils of the Brazilian Naval School, but in a dark night and a heavy sea, it was impossible to distinguish the dangerous point, and two hundred and fifty lives were lost. This disaster, more painful than any preceding it, excited profound sympathy and recalled public attention to the project previously entertained. The emperor of Morocco not only assented to the erection of a lighthouse, but promised, besides, to provide the necessary funds for its construction, on the sole condition that France should appoint an engineer to direct the works.

This mission, which was difficult and ultimately presented many unforeseen obstacles, was confided to M. Jacquet, « conducteur des Ponts et Chaussées », attached to the Lighthouse service, and he immediately proceeded to the locality.

In the month of June 1861, a careful survey, made on board the French man of war *le Coligny,* enabled M. Jacquet to fix definitively the site for the lighthouse. In conjunction with the commander of this vessel, he decided upon a small plateau rising perpendicularly to a height of 70 metres from the sea coast, and situated about 500 metres north-east of the extremity of the cape. This spot commands an extensive horizon towards the open sea, as well as in the direction of the strait, and is free from the dense fogs which sometimes envelop the summit of the mountain.

The locality itself offered some resources in respect of materials for construction, which were the more valuable, as the only means of communication with Tangier are steep and scarcely discernible tracks. This town is the nearest centre of population, and everything brought hence to the lighthouse is carried by asses, a mode of conveyance very expensive and only admitting of small loads.

The plateau is surrounded by rocks of a fine sandstone, sufficiently hard in quality, and easy to work. At a short distance below, a calcareous deposit was discovered, capable of being converted into excellent lime, and near to this were found a stratum of fire-clay and a quantity of sand. Finally, two springs apparently inexhaustible, and slightly ferruginous, bubble up from the rock a few metres above the platform. But in order to take advantage of these resources, it was necessary to open quarries in this desert, to establish lime and brick kilns, to provide dwellings for the engineer and workmen, and to make arrangements for a supply of provisions, etc. But the engineer had at his disposal only forced labour, i. e. men taken from the country adjacent, kept together by compulsion, and frequently changed. In addition to this disadvantage, they were unskilful, and particularly averse to assist in the success of a work, the object of which they did not comprehend, and directed by an infidel whose orders were transmitted to them through the medium of interpreters without authority. In Morocco there are masons not deficient in a certain skill, and who execute very cleverly that ornamental work replete with the graceful fancies so effective in Moorish architecture, but the solidity of construction required in a lighthouse exposed to tropical rains and violent tempests, could scarcely be expected from these workmen. The stonecutters were ignorant of the use of the square, and would not admit the possibility of working stone of larger dimensions than a man could easily carry. The carpenters also have no idea of a framing, and only employ planks. Without doubt, workmen could have been procured from Spain, but the price of labour is so low in Morocco, that the government functionary to whose department the payment of the works pertained, could not make up his mind to pay comparatively exorbitant wages, especially when it did not appear to him absolutely necessary.

The French government came to the assistance of the engineer, and at the close of 1861 sent him a foreman and a stonecutter, and subsequently two other workmen.

At last, owing to the perseverance and energy of the engineer, under the most unfavourable circumstances, this important work was completely finished in 1864, and a light of the first order was kindled at the summit of the tower on the 15th October in the same year.

In order to ensure the regular maintenance of the light, an agreement was made between Morocco, on the one part, and the representatives of the ten powers most interested, on the other, viz. France, England, Spain, Italy, Austria, Belgium, Holland, Portugal, Sweden, and the United States of America.

Each of these powers contributes 1,500 francs per annum, and their representatives at Tangier, forming a commission, decide upon all measures necessary for the proper maintenance of the lighthouse. The keepers are Europeans, and are protected by a Moorish guard consisting of four men and a cadi or commander. This guard is paid by the consular commission.

The edifice consists of a tower, of which the exterior is square and the interior circular. It is situated on one of the sides of a court yard, surrounded with an portico or verandah, under which are the lodgings and storerooms, which are arched, and covered with a terrace. On the outside they are pierced with very narrow apertures, so that when the gate is shut, the guards are protected from nocturnal surprises, and could even hold out against attacks by the natives, until assistance arrived from Tangier.

M. Jacquet the engineer kept the most exact account possible of the expenses incurred by the government of Morocco, expenses with which he had the prudence not to interfere. They were examined and paid by a special agent, an amine, and estimated by M. Jacquet at the sum of .... which includes the purchase of the lenticular or double convex lens apparatus, furnished by MM. Sautter and Company.	256,138 fr.
The expenses borne by the French government amounted to...............	65,736
Total..................	321,874 fr.

XXXVI

LIGHTHOUSE OF NEW-CALEDONIA.

A model on a scale of 0^{m},04 (one twenty-fifth).

The lighthouse represented by this model was erected in 1865 on the islet of Amède, 13 miles from Port-de-France, in New-Caledonia.

It is constructed entirely of iron, according to plans similar to those of the lighthouse of the Roches-Douvres, elsewhere described.

It is founded on a solid mass of beton, in which are sunk the cast iron foot-plates which support the uprights.

The tower is 45 metres in height, from the level of the ground to the platform at the top, and the lantern for the fixed light is 50 metres above the highest tides.

The cost of the iron-work, including putting together and taking to pieces in Paris, amounted to 228,706 fr. 75 cent., which is divided as follows:

Ordinary castings for foundation foot-plates and socle of ground-story, 82,093 kilogrammes at 0^{f},40	32,837^{f},20
Finished castings for door, cornice and stairs, 45,887^{k},48 at 0^{f},55	25,238 ,11
Wrought and plate iron, 193,466^{k},89 at 0^{f},70	135,426 ,82
Wrought iron fittings for door-frames, sashes, balustrades, etc. 17,872^{k},97 at 1^{f},40	25,022 ,16
Three coats of red lead paint, 5,059^{m},23 at 1 franc	5,059 ,23
Bronzes, mahogany hand-rail, glazing, models, etc	5,123 ,23
Total	228,706^{f},75

The idea of constructing a building in stone upon a desert isle could not be entertained in a colony destitute of resources, and the erection of the iron tower presented difficulties sufficiently formidable, but they were skilfully surmounted by M. Bertin, « conducteur des Ponts et Chaussées », to whom the direction of the work was confided. The new light, which is destined to render the greatest service to navigation, was kindled for the first time on the 15th November 1865.

The works were executed by order of the Minister of the Marine.

The authors of the plan were:

MM. Léonce **Reynaud**, inspector general « des Ponts et Chaussées », director of the Lighthouse and Beacon service, and **Allard**, engineer in chief « des Ponts et Chaussées ».

The constructor of the iron tower and the model was M. **Rigolet**.

XXXVII

LIGHTHOUSE OF THE ROCHES-DOUVRES.

Drawings on scales of $0^m,01$ and $0^m,04$.

The plateau of the Roches-Douvres is the most northerly of those innumerable reefs that render navigation so dangerous on the coasts of Bretagne. It is nearly equi-distant between the islands of Bréhat and Guernsey, and twenty-seven nautical miles from the offing of the harbour of Portrieux.

The necessity of erecting a lighthouse on this point had long been recognised, but the construction of a lofty stone tower in a part where the sea, owing to the great force of the tide currents, is constantly rough, was likely to present many difficulties and consequently to involve a considerable outlay, especially as sailing vessels only were available for the service, and these might frequently make fruitless voyages, on account of being compelled to cross the currents, both in going and returning. Steam navigation and the use of iron for purposes of construction appeared to set these questions at rest, and in the sitting of the 24th January 1862, the Lighthouse Commission decided to illuminate the Roches-Douvres by a revolving light of the first order.

The rock upon which it is established is situated near the middle of the south side of the plateau. It rises to the level of flood-tides, and the stone basement of the edifice is $2^{m},10$ in height. The iron tower is $48^{m},30$, from the foot to the level of the upper platform, and $56^{m},15$ to the summit of the lantern. Its diameter, which is $11^{m},10$ at the base for the inscribed circle, diminishes to 4 metres at the top.

The focus of the lighting apparatus is 53 metres above the level of the highest tides.

Cast iron stairs occupy the centre of the building; the store-rooms and keeper's lodgings are situated in the lower part, and are surmounted by two interior galleries, into which shipwrecked persons can be received, and where the workmen can sleep, when exceptional circumstances necessitate their passing some days in the lighthouse.

The lodgings comprise a room in which are stowed the water-tanks, a store-room, kitchen, three rooms for the keepers, and one room for the engineers, when on a tour of inspection. A coal cellar is contrived in the solid part below the staircase.

Up to the present time, the majority of iron lighthouses have been constructed with plates of iron more or less thick, riveted together.

But in the present instance it was not thought expedient to adopt this plan; in the first place, because it causes the stability of the edifice to depend upon a covering greatly exposed to oxidation, and on this account it is deficient in the requisite conditions of durability, especially if neglected. In the second place, because the riveting and mode of construction require special workmen, and also because the scaffolding necessary is difficult to erect upon a rock of limited dimensions. The following conditions were therefore observed:

1. To render the skeleton of the edifice entirely independent of the exterior covering; to shelter it from the sea fogs which rapidly cause oxidation; to facilitate inspection and proper keeping, and to reduce as much as possible the extent of surface exposed to humidity;

2. To manage the process of construction, in such a way, that the tower should be erected without scaffolding at the bottom, and without clinching a single rivet on the place.

Stress was also laid upon the necessity of the parts being of such dimensions as to obviate any difficulties of embarkation, of stowage on board, and of placing in position.

Sixteen great uprights or standards, each consisting of fifteen panels in the height, constitute the skeleton or frame-work of the building. Each panel is in simple T irons, put together, consolidated, and riveted in such a manner as to ensure the most perfect solidarity, and resistance to deformation, contingent upon the strongest shocks or pressures that could be foreseen. These panels are bolted, one upon another, and cross-braces, inside as well as outside, also bolted, keep the standards in position. Finally, on the last cross-braces and on the exterior surfaces of the standards are fitted sheets of iron constituting a covering, the joints of which are protected by wrought iron plat-bands fixed by bolts.

Each standard is surmounted by a cast iron bracket, on which is corbelled out the platform required for the external service of the lantern. The standards rest upon a large cast iron foot-plate held by six wrought iron bolts. and embedded in a solid mass of concrete.

The chambers are surrounded by a brick wall, which, for effectual shelter, is $0^{m},05$ from the sheet iron tower, they have also brick partitions. A floor in concrete raises the surface to $0^{m},40$ above the cast iron foot-plate, while the ceiling is in stone-work resting on small iron joists.

The service chamber is at the top of the tower, and communicates with the lantern by a cast iron step ladder, as usual.

The stairs of the tower are in cast iron with wrought iron stringers. The outer stringer is bolted to the standards where it meets them, and thus contributes to the rigidity of the system. A half turn of the stairs corresponds exactly with the height of a panel, that is to say, $3^{m},20$.

The door of entrance is in oak, with bronze mountings, and all the window frames are in rolled iron.

The T irons are bent according to the angles of the polygon, in order to form the exterior arris of the panels. They are $0^{m},18$ by $0^{m},10$, and weigh 31 kilogrammes per metre. Those constituting the three other sides of the panels are $0^{m},20$ by $0^{m},10$, and weigh 35 kilogrammes per metre. The panels of the three first rows have each a diagonal corner bracket arris-wise, formed of a bar of iron $0^{m},14$ by $0^{m},014$, riveted to two T irons $0^{m},13$ by $0^{m},065$. This bracket, rivets included, weighs 44 kilogrammes per metre.

The cross-braces are in bar iron, $0^{m},08$ by $0^{m},016$, and weigh $9^{kg},689$ per metre.

The thickness of the plates diminishes from the lower story, where it is 0^{m},010, up to the top, where it is reduced to 0^{m},007.

The cover-plates are formed of bar-iron 0^{m},011 in thickness.

The total cost of the construction is indicated in the following table:

Iron tower, properly so called, wrought iron and castings, 317,328 kilogrammes	223,986^{f},76
Joiner's and locksmith's work, bronze hand rail and painting	33,788 ,57
Lantern, lighting apparatus, fog bell	85,576 ,21
Packing and carriage	19,819 ,81
Tools, apparatus for erection, various fittings	17,086 ,02
Foundation work and construction	225,100 ,00
	605,357^{f},37

A temporary light was placed upon the tower during the execution of the works, and was raised at the same time with it.

The actual light was kindled on the 6th August 1869.

The engineers for the iron tower were MM. Léonce Reynaud, inspector general «des Ponts et Chaussées», director of the Lighthouse service, and Émile Allard, engineer in chief «des Ponts et Chaussées».

Constructor : M. Rigolet, of Paris.

The engineers for the foundation works and the construction on the rock were MM. Dujardin and Pelaud, engineers in chief, de la Tribonnière, resident engineer, Bertin, «conducteur des Ponts et Chaussées», and Le Bozec, «employé des Ponts et Chaussées».

XXXVIII

LIGHTHOUSE OF THE HÉAUX DE BRÉHAT.

Three models on a scale of $0^{m},04$ (one twenty-fifth).

The lighthouse of the Héaux de Bréhat is of the first order, having a fixed white light, and is situated about five miles from the most northerly point of the Breton peninsula.

Height of lantern from foundation................	$49^{m},40$
Height of lantern above highest tides.............	$45^{m},00$
Luminous range with the new lighting apparatus.....	20 miles.

The strength of the tide currents in these parts is very great, and they attain a velocity of eight knots. When the force of a tempest is superadded, the violence of the sea is such that the waves rise to a considerable height, and break with a roar against the objects they encounter.

The edifice consists of a cylindrical tower, $47^{m},40$ in height from the arris of the base to the foot of the lantern, and is divided into two principal parts. The lower part is intended to support the strongest pressure and to resist the most violent shocks of the waves, it is therefore constructed with great solidity. With this view, the profile of the exterior follows a concave elliptic curve which gives a large projection to the base; it is 18 metres in height, $13^{m},70$ in diameter at the base, and $8^{m},60$ at the top, and the masonry is solid up to 1 metre above the highest tides. The upper part rests upon a basement considered immovable, while the lightness of its construction might appear suitable for a tower of the same elevation erected upon the land. It is 27^m,40 in height (not including 2 metres for the basement of the lantern), 6^m,80 at the base and 5^m,90 at the top.

The interior diameter of the tower is 4^m,20, and that of the basement of the lantern 3^m,20.

A bronze ladder gives access to the door, which opens to the south, and is placed 1 metre above the highest tides.

The interior of the building is divided into eight stories, communicating by stairs, first straight, then circular with solid newel, of which the staircase is partly let into the wall. The first two stages serve as storerooms and the four following as the kitchen and bedrooms of the keepers, then comes a spare room, a service room, and finally the lantern. The successive diminutions of the diameter of the tower have allowed two exterior galleries to be formed.

To facilitate access, the edifice has not been placed upon the most elevated point, but upon a sufficiently broad platform to the south of the rocky plateau, and 4^m,40 below the highest tides.

The works were established on the island of Bréhat, about 10 kilometres from the rock, in order to take advantage of the facilities for embarking materials, and of the favourable currents of ebb-tide, which tend directly from the island to the site of the lighthouse. Each course was dressed and accurately fitted together before its embarkation, and was afterwards landed at its destination on the rock, and carried to the tower by means of a series of cranes, which passed the stones from one to another.

During the construction of the solid part of the basement, a crane with a long jib, and stayed by six shrouds made fast to the rock, was fixed in the centre of the building on a wooden platform, elevated 3 metres above the level of the highest tides, by means of four uprights. Each of these uprights was secured by five shrouds and two strong iron cramps $0^{m},07$ in diameter, let into the rock, and was enclosed in the filling in of the interior of the tower, and by this means permanently consolidated as the building progressed.

Subsequently, the same crane was placed at the intersection of two trussed girders that rested on the masonry of the tower and were raised by means of jack-screws. The crane lifted the stones and put them immediately into position, the jib being easily varied even when loaded, and finally, a flying scaffolding surrounded the upper part of the building and was raised with it.

The whole construction is executed in perfectly homogeneous granite, of a fine close grain and bluish tint; the vaults are in brick. Notwithstanding the violence of the shocks to which the lighthouse of Bréhat is exposed, it was not deemed necessary to have recourse to the means employed in similar cases to ensure the solidarity of all the stones of the edifice; but each course of the basement was divided into a certain number of great key stones, each of which was fastened to the underlying parts by four granite plugs, let into the two adjacent courses and placed at the angles of the compartment. These arrangements enabled the building to proceed more rapidly and economically, and it may be added that they have since been fully justified by experience.

The works were executed between 1835 and 1839.

The cost, not including the lantern and lighting apparatus, amounted to 531,679 fr. 28 cent.

The works were planned and executed under the direction of M. Lecor, engineer in chief « des Ponts et Chaussées », and by M. Reynaud, resident engineer.

XXXIX

LIGHTHOUSE OF LA CROIX.

Drawings on a scale of $0^{m},04$.

The great entrance passage of Trieux (Côtes-du-Nord) is indicated by two lights; one of which is established on the heights of Bodic, to the left of the embouchure, the other is on an isolated rock which is 2,000 metres from the shore, and is called La Croix. The luminous range of both lighthouses is only required to pervade an angular and limited space, so that the lighting apparatus consists of parabolic reflectors fixed in the upper chambers, in front of the windows opening in the direction of the passage. The lights are twinkling, and cannot be confounded with any other lights on the neighbouring coasts.

The top of the rock La Croix scarcely emerges from the level of the highest equinoctial tides. All the sides of the rock are nearly perpendicular, but between them is an irregular plateau, upon which it was just possible to inscribe the circular base of the tower. This is divided into four stories surmounted by a platform, constituting the sole promenade at the disposal of the keepers. The ground floor serves as vestibule and storeroom, the first story as a kitchen, while the third includes the service room and lighting apparatus.

It was necessary to carry the stairs in a small engaged tower founded 5 metres below the plateau on which the large tower rests.

In order to leave the most elevated part of the edifice in the centre indicated by the light, the stairs do not reach beyond the third stage, and access to the upper platform can only be gained by a movable ladder kept in the chamber of service.

The building is constructed entirely of roughly dressed granite from l'Ile-Grande. The materials were prepared in a work-yard established in the little port of Loguivy, east of the entrance of Trieux. A railway brought them to a special place of embarkation where they were loaded into lighters, which took them to the very foot of La Croix. This transport did not present any difficulty, for the sea is seldom dangerous in these parts, but the currents are so violent that the journey backwards and forwards could only be accomplished at certain hours of the tide. The workmen employed in the construction could not be subjected to these conditions, and they were therefore installed in a small vessel, anchored permanently near the rock. Once only, this vessel broke from her moorings, and was obliged to seek shelter in the port of Loguivy.

The system of placing the materials in position is one of great simplicity, and has already been employed in several similar undertakings.

A loading derrick with an oblique jib, was established on a projection of the rock in that part of the channel where the lighters came alongside. It lifted the materials and deposited them by a rotary movement on some points of rock levelled as a platform. Another similar derrick was placed in the interior of the lighthouse tower, and secured by means of a framing, which was raised successively on the springings of the vault of each stage, in proportion as the construction progressed.

This derrick was placed, not in the centre of the principal tower, but nearer the centre of the stair tower. In this manner the materials collected on the platform of deposit could be carried by the rotation of the jib to one tower or the other, very near the desired position. Besides, this arrangement, by leaving the central axis of the tower clear, permitted an apparatus of verification to be put up, formed of a radius movable round the centre, and which was marked from top to bottom of the construction by a plumb line.

The stone-work was commenced in May 1865, and finished at the end of 1866. The only stoppage experienced was in consequence of the tempests of this latter year, which for long intervals completely hindered the supplies of dressed stone.

Excepting the supply and preparation of materials, the works were entirely executed under the direction of MM. Dujardin, engineer in chief, and de la Tribonnière, resident engineer, and under the assiduous management of M. Beaugrand, conducteur.

XL

LIGHTHOUSE OF CRÉAC'H.

(ISLAND OF OUESSANT.)

Drawings on a scale of $0^{m},04$.

The former lighthouse of Créac'h was established on the eastern extremity of the island of Ouessant, but the present edifice is erected on the western point, and is better calculated to indicate the landfall desired not only by vessels wishing to enter Brest, but by the majority of those arriving from the open sea, and attempting to make the entrance of the Channel.

The building consists of a tower 43 metres in height, from the level of the ground, and of subordinate buildings containing storerooms, chambers reserved for engineers, and three lodgings for the keepers and their families. A covered passage connects the tower with the outbuildings. Behind the buildings is a service-yard.

The interior of the tower is a cylinder 4 metres in diameter, in which is fixed a winding flight of stairs in open work, composed of 184 steps and making about five circuits and a half. These stairs are lighted by eighteen windows, and the ascent to the service room is continued by a cast iron ladder. A second ladder of the same material puts this chamber in communication with the lantern, the diameter of which is also 4 metres, and the surrounding space is covered with marble paving.

The subordinate erections consist of a main building, 42 metres in length by $7^m,70$ in breadth, and two wings.

The keepers' lodgings are completely separated from each other. Each is composed of a kitchen, chamber and cabinet on the ground floor, with attics to correspond. A special stair-case for each keeper leads up to the attic belonging to him, and each lodging has its private doors, opening on the front as well as on the service-yard.

The reserved apartments consist of a chamber and cabinet for the engineer, with the same accommodation for the conducteur.

The lighthouse is supplied with water by means of two cisterns, which receive it from the roofs. These cisterns are situated, one in the front court, the other in the service-yard.

Independently of these works which constitute the lighthouse establishment proper, and that have made the principal object of the undertaking, their accomplishment has required the execution of others of some importance, that have not been included in the contract. Such as the construction of a small port, and the opening of a new road of 3 kilometres, to facilitate the discharge and transport of materials which arrive from the continent.

The lighthouse of Créac'h was established on a plateau of granitic rock previously levelled. With the exception of the basement, the cornice, and the window and door framings, it is built in rough quarry stone, covered with a layer of Portland cement. Up to the springing of the cornice, the masonry of the tower was executed with mortar of hydraulic lime from la Rochelle, but the capping of the edifice was laid entirely in Portland cement. The dressed stones of the tower are in Kersanton granite, those of the subordinate buildings are in granite of the island.

The stone-work of the tower was executed without any exterior scaffolding; all the service of materials was done in the space occupied by the stairs, and no accident attended the work which was commenced in 1860, and finished in 1863.

The cost amounted to 363,596^{f},51^{c}, including the lighting apparatus.

The plan of the lighthouse was designed by M. de Carcaradec, resident engineer. The works were executed under the direction of MM. Maîtrot de Varennes, engineer in chief, and Rousseau, resident engineer.

Conducteur, M. Delachienne; contractor, M. Tritschler.

XLI

LIGHTHOUSE OF LE FOUR

(FINISTÈRE).

Drawings on a scale of 0^{m},02 and 0^{m},04.

The lighthouse of le Four is situated on the most advanced rock at the extreme north of the channel of this name, and is two miles west of the little port of Argenton. This rock, which is of very hard granite, rises to about 2 metres above high tides, and any degree of agitation in the sea renders it inaccessible. In bad weather, the waves break so heavily and with such violence, that they dash above the lantern of the lighthouse, and have broken shutters of 0^{m},06 in thickness, which closed the narrow windows of the tower, during the execution of the works.

The dépôts and yards for cutting and dressing the stones were established in the port of Argenton, whence the craft, which carried the workmen and materials to the rock, started when the weather and sea permitted. Steps cut in various places enabled the workmen to mount the steep and slippery sides, and a crane simple in construction, and offering no hold for the waves, served to land the materials.

The lighthouse consists of a tower, having an interior diameter of 4^{m},50, and is erected upon a solid mass of stone-work levelled to 2 metres above the high tides of the equinox, and embedded in the rock, the highest points of which it completely envelops. The wall is $2^{m},75$ in thickness at the base and $1^{m},18$ at the top. The larmier of the upper cornice is supported by sixteen corbels, and above this is a parapet consisting of slabs $0^{m},20$ in thickness, and arranged in pilasters.

Above the solid base, the height of the tower is $22^{m},70$, and at this point it is surmounted by a ten sided polygonal sheet-iron support for the lantern $2^{m},40$ in diameter. The focal plane thus exceeds, by 28 metres, the level of the highest tides.

The masonry is in rubble work of granite, laid in a mortar-bath of Portland cement, with facings of dressed ashlar. The steepness of the southern declivity of the rock necessitated the greatest precautions in founding the lighthouse. Deep concentric redans were cut into the rock, inclining towards the centre of the tower, and a number of iron gudgeons, $0^{m},07$ in diameter, bound the first courses of masonry together. All the stones of the string-course are also held with iron cramps, and a strong iron band is let in above the corbels of the cornice. The pilasters of the parapet are secured by bronze sockets.

The tower is composed of a ground floor and five upper stories. The ground floor, and the four stories above, communicate by stone stairs, commencing at the end of the entrance passage. The stairs are first straight, then circular, with a newel, and have 94 steps, and the staircase is partly let into the thickness of the wall. A partition of moderate thickness separates it from the chambers. It stops at the fourth story, from which floor the upper story and lantern are reached by means of wrought and cast iron hanging ladders, so placed as to occupy little room.

The ground floor is divided into three compartments, the vestibule and two paved vaults, each lighted by a window $0^m,50$ by $0^m,25$. The left vault contains a coal cellar capable of containing 5,000 kilogrammes, and filled from the stairs; also a force and suction pump for the supply of water. The right vault is the oil dépôt. On the first story is the storeroom in which are twenty two iron tanks holding 5,000 litres of fresh water; also two coal bunkers containing together 2,000 kilogrammes, and placed on either side of the door, in the angles formed by the projection of the staircase into the interior cylinder of the tower. On the second floor is the kitchen; the stove is placed in a niche from which a deep groove, $0^m,30$ in breadth by $0^m,45$ in depth, is formed in the wall and extends to the upper platform. In this groove is fixed the copper chimney-pipe of the stove. The corners of the projection of the staircase are utilised as two cupboards. The third story is the bedroom, in which are two beds and two cupboards, similar to those in the kitchen. On the fourth floor is the steam-trumpet room, but the trumpets themselves are above the service room on the fifth story. The ground floor and the two first stories are vaulted, as is the fifth; the former cylindrically, the latter spherically. They are all in Bristol bricks except that of the fifth floor, which, being pierced by the service stairs, is entirely in granite. On the third and fourth stories, with the view of gaining space, a framing, consisting of seven iron plate girders cross-braced, has been substituted for the vaulting, and supports small brick arches.

The entrance door of the lighthouse and the outer windows are in oak, with a coating of boiled linseed oil. The interior windows, floors, wainscot frames, room and cupboard doors, plinths and cornice mouldings are in oak, waxed. The panels are pine, also waxed. The lower windows and the two first outer windows of the staircase are fitted with dead-lights similar to those used on board vessels.

All the locksmith's work is in bronze, and mostly on special models.

The trumpets, to which recourse is had in time of fog, and when the light is not visible, are ordinarily put into action by air compressed in a reservoir by means of a steam-engine. In the present instance, want of space precluded the adoption of this method, and another plan was followed, invented by professor Lissajoux. This apparatus, which is clearly shown in the drawings, consists of : 1. Two vertical Field's boilers coupled, of a total of four horse power. 2. A trumpet with apparatus for producing a rush of air by a jet of steam. 3. A distributing machine moved by steam, opening and shutting, at intervals, the communication of the boilers with the trumpet, so that the sound is produced at the rate of one blast per five seconds. 4. A clock regulating the steam distributor.

The sound of the trumpet is conveyed through an iron cone, fixed in a circular opening formed in the west-southwest side of the tower wall. The smoke of the fuel issues through a copper pipe, joining the kitchen stove pipe, in the groove made for that purpose. The necessary pressure of steam can be got up in twenty minutes, at most, after lighting the fires.

The boilers are supplied with fresh water, and the consumption, with the cadence adopted for the trumpet, is about 25 litres per hour. A suction and force pump, placed in the western vault of the lighthouse, pumps fresh water from boats alongside the rock, and discharges it into the twenty-two iron tanks placed in the first story. These tanks hold 1,250 litres, intended for the keepers, and 3,750 litres for the boilers, which are thus provided with sufficient water for 150 hours of work at least, without the supply being renewed.

The water is raised from the tanks to the feed-reservoir in the trumpet chamber, by means of an injecting apparatus put in motion by a steam-cock fixed on the boilers.

On the western coast of Finistère the lights are numerous, in proportion to the difficulties and importance of navigation in these parts, and it was therefore essential to give to the lighthouse of le Four a distinctive character which should prevent its being confounded with any other.

The lenticular apparatus of the third order, which makes part of the exhibition of the Ministry of Public Works, was designed with this view. To a fixed light for half a minute, there follows for the same period of time a light with eclipses, the intervals of which are fixed at $3 \frac{3}{4}$ seconds. The illuminating power consists of lamps with three concentric wicks, fed with mineral oil.

The works of the lighthouse of le Four were undertaken in 1869, and the light was kindled, for the first time, on the 15th March 1874.

The total cost of construction, including optical apparatus and steam-trumpet, amounted to 308,888f 21c, and the expense per cubic metre of masonry, to not more than 150 fr.

The edifice was planned and executed by M. PLANCHAT, engineer in chief «des Ponts et Chaussées», and M. FÉNOUX, resident engineer, and the works were directed by M. BOUILLON, conducteur.

The lighting apparatus was made by MM. HENRY-LEPAUTE.

The steam-trumpet is due to MM. LISSAJOUX and FLAUD.

XLII

LIGHTHOUSE OF LA BANCHE.

Two models on a scale of 0^{m},04 (one twenty-fifth).

The lighthouse of la Banche was commenced in 1861. and the light kindled on the 15th August 1865. It is situated west-south-west of the embouchure of the Loire, 9,500 metres from the nearest land, 13 kilometres from Pouliguen, and 24 kilometres from Saint-Nazaire, the only ports in which the materials could be prepared and embarked.

It is established on the bank of le Turc, which at ebb-tides is only a few decimetres above the surface of the water, and forms part of the great plateau of la Banche extending from north-west to south-east, a length of 7 kilometres, with a breadth varying from 1,500 to 2,500 metres, and separating the northern and southern channels. This plateau constitutes the most serious danger in entering the Loire, for at low tide there is only from 1 to 5 metres of water, and it is thickly studded with projecting rocks. Like all those of the second line of reefs, on this division of the French coast, it is formed of calcareous rocks of the tertiary group.

The currents are not very strong in the vicinity of the plateau, but when the great billows of the Atlantic roll in and break upon this species of barrage, without having previously encountered any obstruction to their course, they acquire such violence, that, during the winter that followed the completion of the masonry, masses of water not only dashed up to the top of the tower, and over the cornice which projects considerably, but dislocated, solid as it was, the frame-work of the conical roof temporarily fixed on the building.

The great distance of the lighthouse from the ports of embarkation of the workmen and materials rendered it inexpedient to return after each tide. This would have caused great expense and loss of time; the small vessels therefore, employed in the work of transport, anchored in the vicinity as frequently as the state of the sea permitted. This little fleet consisted of two lighters, of from 40 to 50 tons measurement, a little steam sloop, of 10 horse power, and three large boats, one of which was a life-boat. Craft of a larger tonnage could not be employed, on account of the necessity of starting from the port of le Pouliguen at every tide, and of finding refuge there in case of need.

Unless in a calm altogether exceptional, the bank of le Turc can only be approached at one point on the northern side, and it was therefore decided to place the lighthouse in the neighbourhood of this point. But upon commencing the foundations, it was soon perceived that what appeared to be the rock was in fact only an enormous mass of calcareous stones of considerable size, which had been wrenched by the sea from the plateau of la Banche, and cemented together by sand and mud. It was necessary however at any price to establish the foundation on the solid part of the bank, and this was only discovered at a distance of 95 metres south of the point of debarkation, and exposed to the full force of the sea. The depths varied from $0^{m},90$ to $0^{m},20$ only, above the level of low spring tides.

The surface of this rock was hard, and without many fissures: it appeared at least to ensure a good foundation; but when the excavations were commenced for the first courses, it was observed that in many places the rock became softer, and sometimes changed into a mass of calcareous matters not solidified, and of the consistence of muddy sand. Under these masses, the rock was found solid at depths varying from $0^{m},60$ to $2^{m},10$; but numerous soundings showed that they did not constitute a continuous stratum, and that they only occupied small cavities more or less important. In order to obtain the extent required, it was necessary to seek these intervals of solid with the greatest care, and to clear them from the detritus. This was effected at each tide by means of coffer-dams hastily constructed; most frequently of the seaweed close at hand. They were then packed with a mortar-bath of Portland cement to a depth, in some cases, 2 metres below the lowest ebb-tides.

While these difficult foundations were being laid, the landing and conveyance of materials also occupied attention. The various vessels employed could not be brought alongside the southern part of the bank, and a dike was therefore formed across it, more than 100 metres in length, the top of which was raised $0^{m},50$ higher than the average level of the sea, and made sufficiently broad to allow a line of rails to be laid in order to convey to the foot of the lighthouse the materials landed at the northern point, where the vessels could come alongside, and where a crane was established to discharge them. This dike, traced from north to south, tangentially to a circle of 10 metres radius, concentric to the tower, followed at its southern extremity this circle for about 120 degrees, and protected the first part of the stone-work against the waves from the south-west, and against the first strength of the rising tide. It was quickly executed with rough stones from the bank itself, laid with rapidly hardening cement, and finished at the same time as the foundations. These last were commenced on the 14th May 1862, after two months of soundings and preparatory work, and at the end of the season had attained a height of 1 metre above the lowest tides.

This result was only obtained by remaining at the anchorage as long as the sea permitted, in order not to lose one of the few hours available under the circumstances, and this proceeding ensured the comparatively rapid completion of the undertaking.

The lighthouse was planned according to the type of sea lighthouses of the third order, and was to consist of a stone tower, of which the elliptic basement would rest on a solid foundation 1m,60 in thickness. But, taking into account the unsatisfactory nature of the rock, it appeared expedient to diminish the height of the tower, and to increase the thickness of the foundation by 1 metre of stonework laid with mortar of Portland cement, in equal parts of cement and sand. This course of action was not dictated by the idea of lessening the weight of the tower, since the cube of the masonry remained evidently the same (1,224^{m},83 instead of 1,228^{m},67), and moreover the pressure per square centimetre was already very small (1^{kg},68), but really to reduce the lever power tending to overthrow, exercised by the shocks of the waves, and to establish the tower on a veritable monolith, sufficiently solid to withstand without damage the inequalities of resistance offered by the foundation bottom. The total height of the work is 26^{m},525, and the focal plane of the lighting apparatus is 21^{m},225 above the highest tides, an elevation sufficient for the range assigned to the light.

The tower includes a cellar, vestibule, kitchen, two keeper's rooms and a service room. With the exception of some minor modifications of details, of which the models only can convey a correct idea, it is capped and arranged similarly to all other sea lighthouses of the third order.

The threshold of the entrance door is only 2 metres above the highest tides, but as this door is placed on the northern side, and sheltered from the waves of the offing, the sea rarely reaches it, and never so violently as to excite apprehension. It was only necessary to use means for the protection of the window, and to this end a thick copper shutter is fitted into a bronze frame meeting the double curve of the basement facing.

All the stairs are in cast iron with sheet-iron stringers. For the ordinary brick or stone vaulting, floors have been substituted, formed of strong girders of plate and angle-iron, of which the spaces are filled with brick work.

This plan was adopted not merely with the view of increasing the volume of air in the chambers, but to furnish additional support to the hollow part of the tower, which is also sustained by three wrought iron bands $0^m,050$ in thickness by $0^m,070$ in breadth, embedded in the masonry at different levels.

The catadioptric apparatus gives a fixed red light.

The upper part of the foundation was executed in very hard granite from the quarry of Lavau, which also supplies the works at the port of Saint-Nazaire. The cornice, capping of the lighthouse, and base of the lantern, are in fine granite from la Conterie, near Nantes. In the rest of the edifice, the coast granite was exclusively used in the exterior as well as the interior facing, in the form of dressed ashlar, $0^m,225$ in height of course, $0^m,50$ length of average pendant (without going below $0^m,40$), and $0^m,40$ to $0^m,55$ in length, except for the framings of openings, which are of longer dimensions.

The works, transport and setting of materials, were executed entirely «en régie».

The cost amounted to $374,280^f,85^c$, including the lighting apparatus.

The lighthouse of la Banche was planned and executed under the direction of M. Chatoney, then engineer in chief «des Ponts et Chaussées», by M. Leferme, engineer «des Ponts et Chaussées».

The works were conducted by MM. Salley, conducteur, and Butat, secondary agent.

XLIII

LIGHTHOUSE OF THE BARGES.

Three models on a scale of 0^{m},04 (one twenty-fifth).

The lighthouse of les Barges is one of the third order, and shows a white light, varied at intervals of three minutes by red flashes. It is 2,100 metres from the coast, and is situated on the west of les Sables-d'Olonne, on the plateau of the great Barge d'Olonne, which is about 600 metres in length by 300 metres in breadth, and is entirely under water, with the exception of a few points emerging here and there in isolated groups.

Luminous range	14 milles.
Height of focus above flood-tides	23^{m},00
Height of focus above foundation bottom	27^{m},50

The cylindrical tower is 24^{m},81 in height above the rock, not including the turret of 2 metres. It is solid, and has elliptic facings up to 4 metres above the highest tides, or 8^{m},50 above the rock, where the hollow part commences. The basement is 12 metres in diameter at the base, and 6^{m},50 at the upper part. The hollow part is 16^{m},31 in height and 3^{m},50 interior diameter; and the walls are 1^{m},50 in thickness at the base and 0^{m},77 at the top, which constitutes a diminution of 0^{m},045 per metre.

At Barges the tide currents are not very strong, but the violence of the sea is such that the spray sometimes rises to a height of more than 30 metres, and falls on the cupola. This reason dictated the expediency of so large an extent of basement, also its execution in solid masonry with facings of dressed granite, fastened by tenons and mortises.

The entrance door, to which access is gained by a ladder let into the masonry, is placed 4 metres above the highest tides. At this level commences the hollow tower, the walls of which are entirely in roughly dressed granite. It is divided by brick vaults into five stories connected by stairs; in stone for the lower story, and in cast iron for the others. A double cincture in bronze consolidates the tower from the upper vault.

A cellar containing water-tanks, a coal-bunker and a depot for various articles, has been formed in the basement.

The foundations presented very great difficulties. It was not found practicable to place the edifice on the point most elevated and most convenient for approach, as in that place the rocks were detached and full of fissures. This circumstance compelled the adoption of a site most exposed to the sea, and of which the average level was only 0^{m},50 above low spring-tides, and 0^{m},80 below low neap-tides. The irregularities of the surface, and the inclined veins that it presented, led to the first course of the facing being let 0^{m},25 to 0^{m},30 into the rock, in order to prevent sliding. Two seasons were required to accomplish the levelling, those of 1857 and 1858: at the same time it ought to be mentioned that the rock is of extremely hard granite, so that not more than twelve stonecutters could be employed at once, and that the number of actual working hours was only thirty-eight in 1857, and forty-five in 1858.

The necessity of protection from the waves was recognized from the commencement of the works, and for this purpose two jetties were constructed, one of which is 75 metres in length and 3 metres in breadth, with the top made flush with the level of high neap-tides.

The stones of the first four courses were landed and set by means of temporary appliances, consisting of a landing crane, let into a post fastened to the lighthouse, and a setting crane, movable on a circular plate fixed in the central stone-work.

In the month of July 1859, more powerful apparatus was put up, consisting of a safety top and lifting sheers, which served to raise the stone-work of the basement to the level of high neap-tides; but in the month of October following, the whole was carried away by a tempest of extraordinary violence.

In 1860, it was necessary to have recourse to new machinery, prepared during the winter, and comprising a landing crane, a setting crane, and a crane for lifting and setting, for the construction of the hollow tower. These different appliances are represented in the model.

All the masonry, except one part of the interior of the solid basement, was executed in Portland cement mortar, in the proportion of 1 part of sand to 1 of cement for the dressed stones, and 2 of sand to 1 of cement for the rough stones and bricks. The filling in of part of the basement, below the level of the highest tides, was effected with rapidly setting cement mortar from the isle of Ré, in the proportion of 1 part of sand to 1 of cement.

The works were commenced in 1857 and terminated in 1861. During these five seasons the workmen were able to land 346 times, and in all to work at the lighthouse 1,960 hours, and at the jetties 308 hours.

The total cost amounted to 450,000 francs, of which sum nearly 80,000 francs were for accessory works.

The lighthouse of les Barges was planned by MM. Petot, engineer in chief, and Lancelin, resident engineer. The construction was carried on under the direction of M. Forestier, engineer in chief, of M. Legros, resident engineer, from 1857 to 1858, and of M. Marin, resident engineer, from 1858 to 1861.

XLIV

LIGHTHOUSE OF LA PALMYRE.

Drawings on scales of $0^{\mathrm{m}},02$, $0^{\mathrm{m}},04$ and $0^{\mathrm{m}},20$.

Tower and dependencies. — The lighthouse of la Palmyre is situated in the middle of the downs on the right bank of the Gironde, and five miles inland from the point of la Coubre. Concurrently with the lighthouse established on this point, it is intended to point out the first line of direction at the entrance of the northern passage of the embouchure of the river, also to enable vessels to avoid the bank of la Mauvaise, of which the slow and steady progress north-north-east, has led to an alteration in the line of beacons formerly placed in this passage, and which had become dangerous.

It was not considered expedient to erect a building of stone in this place, partly because of the difficulties presented by the transport of materials, and partly on account of the probability that ultimate changes in the channel of the passage might necessitate the removal of the lighthouse to another site. This latter consideration had already suggested the employment of timber in the construction of the great lighthouse of Pontaillac, in the same district. It was therefore decided to erect an iron tower, after a new system invented by M. Lecointre, engineer de la Marine and of the Mediterranean Company of Forges and Workshops.

The shaft of the tower consists of nine cylindrical tubes, each $2^{m},80$ in height, fitted one upon the other, and forming a staircase 2 metres in the interior diameter. These tubes, 2 tons in weight, are composed of six plates of iron $0^{m},01$ in thickness, bound together by exterior vertical cover-plates, riveted, and bordered at their upper and lower extremities by two angle-irons $\frac{120 \times 120}{10}$, riveted on these plates. Bolts fasten each tube to the preceding and succeeding tubes.

In each division of the pillar the stairs are lighted by a small window, and are composed of sixteen steps in striated iron plate, $0^{m},80$ in average length, fastened to two rows of angle-irons, one of which is fixed to the interior of the tube, and the other to a hollow cylindrical newel, 40 centimetres in exterior diameter.

The nine tubes form a pillar $25^{m},20$ in height, having a solidarity with the foundation, which consists of concrete 3 metres in thickness, run into the sand of the down on which the lighthouse stands. The tube is connected with the foundation, both at the top and at the base. For this purpose, flanged cast iron shields or plates, embedded in the lower part of the concrete, serve as points of holding for bolts, which traverse the whole thickness of the foundation. The heads of these bolts are fixed in the plates, on the one part, at the base of the first lower tube, by riveting, and held on the other part, by a double system of screw nuts. This plan of connecting the base of the tower with its foundation, is also employed to attach the two upper tubes of the column to the same solid mass.

With this view, two tubular iron struts are riveted by means of elliptic angle-irons to the eighth and ninth tubes, and are fixed to the plates in the same manner as those that sustain the column.

The plane of the mass of concrete is in the form of an equilateral Y, of which each branch is 4 metres in breadth and is terminated by a semi-circle, having its centre at 5 metres from the axis of the tower. The central pillar is maintained in position by six bolts, 0^{m},07 in diameter and 3^{m},67 in length, and rests upon a vertical monolith socle 0^{m},40 in height. The axis of each of the three struts meets the surface of the concrete in the centre of the circumference which terminates each branch of the Y. These struts are fixed at their base to four foot-plates, by means of a similar number of bolts, 0^{m},07 centimetres in diameter and 3^{m},67 in length, held, in the same manner as those of the centre, by cast-iron plates. These four foot-plates rest on a cylindrical socle, forming one with the solid concrete, and of which the surface is perpendicular to the direction of the strut. The foundation bolts are respectively parallel to the struts which they fasten. The cylindrical lengths of the struts, and of the newel of the stairs are jointed to each other, so that the upper extremity of each division is covered for about 0^{m},10 of its length by the lower portion of the part surmounting it, and these junctions are secured by rivets.

The column occupied by the stairs has above it a cylindrical construction, 4^{m},20 in interior diameter, which is divided into three parts: service room, apparatus room and roof. An exterior gallery, 0^{m},90 in breadth, affords from the service room, a promenade round the edifice, and is supported by brackets; it has also a guard rail of sheet-iron.

This upper part is composed of twelve sheets of iron joined together in the interior by vertical angle-irons. Each of these cylindrical segments is covered by a panel in teak 0^{m},04 in thickness. The service room is 3 metres in height; it contains the cylinder of the stair landing, a small room for the keepers and a little storeroom; a wrought iron ladder puts it in communication with the light room. A small outer gallery is placed below this last room, to facilitate the daily cleaning of the glass through which the luminous rays pass. A perpendicular tube in sheet-iron, 0^{m},80 in diameter, allows access from the light room to the top of the roof, and by passing through a man-hole the necessary repairs can be executed. By means of hooks fixed in the roof, and of apertures in the floor of the lower platform of the lantern, an exterior movable scaffolding can be established for the purpose of renewing the paint on all the surfaces of the tower, in order to prevent oxidation.

The keepers' house and the out buildings dependent upon the establishment are constructed on the abrupt declivities of the down, a short distance from the lighthouse, and are in brick. The light was kindled for the first time on the 1st September 1870.

The cost amounted to the sum of 134,268 fr. 55 cent. divided as follows:

Road of access	27,752^{f},38
Foundations, keepers' house and out buildings	29,935 ,37
Iron tower	76,580 ,80
Total	134,268^{f},55

Lighting apparatus. — The luminous rays of the light of la Palmyre are concentrated in an angular space of 45°, and show red and green alternately, during intervals of twenty seconds, without the interposition of eclipses. The apparatus is composed of a dioptric and catadioptric lens with a fixed light, embracing an angle of 150°, also of a catadioptric reflector placed in the opposite angle to the preceding, and two groups of vertical prisms arranged in front of the fixed light, in the space on each side of the centre, and outside the angle to be illuminated. These elements have been calculated in such a manner as to concentrate the rays proceeding from the fixed light, and to distribute them as uniformly as possible in the useful angle of 45°.

Between the fixed light and the vertical lenses, is a circular screen formed of three sheets of glass, each commanding 75°; the two outer sheets are red, the centre one is green. The mounting or frame bearing this screen receives an oscillating movement, by means of which the light passes rapidly from one colour to the other, and retains, during a given time, a constant tint.

The apparatus is placed upon a plate and cast iron socle, in the interior of which a machine moved by a weight gives a uniform rotary motion to a vertical shaft. The regularity of this movement is ensured by a Foucault regulator. On the shaft is fixed a horizontal plate having a groove formed of two arcs with different radii, concentric to the vertical shaft, opposite to each other, and connected by waving or sinuous lines. A little roller. attached to the oscillating support of the screens, penetrates into this groove and remains motionless, so long as it is in one of the circular parts. But when the rotary motion of the shaft brings the roller in contact with one of the lines of junction, it is compelled to move until it arrives at the other arc, where it remains immovable as before.

By means of this arrangement it follows that the screen describes an angle of 75° in four seconds, that it remains without motion sixteen seconds, that it afterwards performs a movement of oscillation in the reverse direction, and remains immovable as before. This movement brings successively before each part of the light, now the green, now one of the red screens, in such a manner as to produce the kind of light designated.

The illumination is produced by a mineral oil lamp, having a burner with three wicks.

The engineers were MM. **Lecointre**, engineer in chief of the Mediterranean Company of Forges and Workshops, **Marchegay**, engineer in chief «des Ponts et Chaussées», and **Lasne**, resident engineer. The lenticular apparatus was composed and calculated by M. **Allard**, engineer in chief «des Ponts et Chaussées». The apparatus and rotary machine were executed by MM. L. **Sautter**, **Lemonnier** and Company, lighthouse constructors, Paris.

XLV

LIGHTHOUSE OF SAINT-PIERRE DE ROYAN.

Drawings on a scale of $0^m,04$.

The embouchure of the Gironde presents two distinct passages, tending eastward in directions nearly at right angles to each other. The northern passage is wide and deep, and most used by vessels; the other, the southern passage, though less practicable for navigation, offers great advantages, even for ships of large tonnage, when vessels enter it with the wind in the south and at the turn of the flood-tide.

The two lighthouses of Saint-Pierre de Royan and du Chay, distant from each other 2 kilometres, are intended to light the latter passage, and to replace advantageously, on the right bank of the river, two of the old beacons, which were only useful during daylight. In order that no confusion might occur in these arrangements for the safe navigation of the embouchure, which was already provided with a great number of lights, the two lighthouses in question only illuminate an angular and limited space. The apparatus is placed in the upper chambers of the edifices, in front of windows opening in the direction of this passage, and consists of spherical reflectors which throw back the luminous rays from the focus upon lenses «à échelons», of which the parallel optical axes are situated in the vertical plane of the line of direction required. There is only one apparatus in the lighthouse of le Chay, while there are two in that of Saint-Pierre, on account of the greater distance of the tower. All these lights are red and fixed.

The edifices consist of stone towers, of a rectangular form, and the interior arrangements are the same. The most important is that of Saint-Pierre.

The plan of this building is that of a perfect square, the measurement of which is 5 metres throughout the whole height of the tower. A small party wall of 20 centimetres serves as string-wall parallel to the exterior, and separates the staircase, of which the breadth is 2 metres, from the reserved chamber on each story on the side of the façade.

These rooms are eight in number, including the ground-floor, and are consequently 2m,80 in breadth by 5 metres in length.

The ground-floor serves at the same time for vestibule and reception room; the oil room is on the first story; the 2nd, 3rd, 4th and 5th stories constitute lodgings for the keeper and his family; the service and light rooms are in the upper part of the building.

This edifice is intended to serve as a landmark during the day, and to render it more clearly visible, and obviate at the same time the possibility of confounding it with the steeples of the town of Royan, the upper part has been enlarged by means of wing walls, corbelled out 1m,50 on each side. In addition to this, it is covered with broad horizontal bands, alternately red and white. The signal on the top of the tower stands out against the sky, and is painted entirely red.

This light was kindled on the 15th June 1873.

The plans were drawn up by M. **Reynaud**, inspector general, by M. **Lasne**, resident engineer, under the direction of M. **Marchegay**, engineer in chief.

The works were conducted by M. **Sauvion**, « conducteur des Ponts et Chaussées ».

XLVI

LIGHTHOUSE OF AR-MEN.

Drawings on scales of $0^{m},015$ and $0^{m},04$.

The island of Sein is situated on the western extremity of the department of le Finistère and extends in a westerly direction by a succession of reefs, to a distance of nearly 8 miles from the island, and lower proportionably. The tops of some are elevated above the highest tides; others are alternately above and below the surface of the water, while the greater number are always submerged. They constitute a sort of barrage, the direction of which is nearly perpendicular to that of the tide-currents, and the sea almost constantly breaks over them with extreme violence.

This singular geological formation, known by the name of the causeway of Sein, has acquired a sad celebrity amongst nautical men, and in 1825 it occupied the attention of the Commission appointed to elaborate our system of maritime lighting.

The plan adopted, and at that time it was impossible to propose a better, consisted in erecting two lighthouses of the first order: one on the point of le Raz, the other on the island of Sein, to mark the direction of the causeway. Mariners are clear of danger, and know on which side they are, when the lights open out from each other. On the other hand, when the luminous points are nearly in the same line, it warns them to make a greater offing, to avoid striking on the reefs. But nothing enabled them to judge of this distance, and it does not require a very thick fog to prevent the lights from effectually indicating the limit of danger, and in such a case they are of little use. For this reason the causeway of Sein continued to be the scene of mournful disasters, and the former system of lighting had only the effect of reducing the number of wrecks, while our navigators for whose security so many precautions are taken at the present day, complained at different times of this state of things.

In April 1860, the Lighthouse Commission demanded that the subject should be properly investigated, in order, to know if it would not be possible to erect a lighthouse of the first order on one of the rocks not covered by the sea, and as near as possible to the extremity of the causeway. The idea was approved on the 3rd June following, and the first surveys of the locality were confided to a commission composed of engineers and officers of the navy. In July of the same year, this commission had made a careful examination of the local conditions, and had ascertained that the heads of three rocks emerge from the water near the extremity, even in strong tides. Of these rocks, which bear the names of Madiou, Schomeur and Ar-Men, the two first are nearly covered, while the third rises to about 1^{m},50 above the lowest ebb-tides. The state of the sea had not permitted them to go alongside Ar-Men, but its dimensions appeared insufficient for the construction of a great lighthouse, and it appeared impossible to land, however favourable the weather might be. The commission were therefore unanimous in proposing as a site the rock Neurlach, which is situated 5 miles inwards from the extremity of the causeway. This idea was repudiated by the Lighthouse Commission, as not tending to ameliorate the existing state of things sufficiently for the requirements of navigation, and the Ministry of Marine was requested to command a thorough hydrographic exploration of the extremity of the causeway.

Various circumstances retarded the execution of this work. In 1866 M. Ploix, engineer and hydrographer, was sent to the spot, and if he was not able to gather all the information necessary, still his investigations enabled the Commission to decide upon a plan. M. Ploix arrived at the conclusion that Ar-Men was the most proper site. «It is a work,» said he, «exceedingly difficult, almost impossible, but considering the paramount importance of lighting the causeway, we must try the impossible.»

The currents passing over the causeway of the Sein are in fact most violent; their speed in high tides exceeds eight knots, and in the calmest weather they cause a strong chopping sea, and render the water very rough as soon as a breeze from an opposite direction meets them. There is no land to shelter the rock against winds from between the north and east-south-east, round to the south, and it is only possible to go alongside during very gentle winds between north and east.

To anchor a floating light at the extremity of the causeway had been recognized to be impossible, as much on account of the great depth of water, as in respect of the bottom being thickly studded with rocks, around which the holding cable would be entangled.

Neither was it possible to entertain the idea of establishing an iron structure resting directly on the reef, since boring holes $0^m,18$ or $0^m,20$ in diameter, that would be necessary for embedding and securing the standards, would be one of the longest and most difficult operations. It was also observed that the principal planes of cleavage were vertical, and it was to be feared that the structure would not resist the shocks it would have to support; and it would be almost impossible to land the different pieces of the iron framing, necessarily heavy and difficult to handle, and finally there would be the risk of losing several before succeeding in putting them in position. Taking into account these various considerations, the Lighthouse Commission, in its sitting on the 29th November 1866, gave an opinion that a solid foundation of masonry must be established on the rock Ar-Men, and that it must be of such dimensions as would be suitable for the ultimate construction of a lighthouse.

Neither the Commission of 1860, nor the engineer hydrographers, nor the engineers of the department, nor their sailors, nor the director of the Lighthouse service had hitherto succeeded in landing on the rock. M. Ploix had not been able to get nearer than 15 metres; but M. Joly, engineer, was more fortunate, and the sketches that he took, and afterwards finished from the descriptions of the fishermen, gave the starting point of a system of construction. The dimensions of the rock were ascertained to be 7 or 8 metres in breadth by 12 to 15 metres in length, at the level of ebb-tides; also that the surface was very unequal and divided by profound fissures, and that, while almost perpendicular on the eastern side, there was a gradual slope on the western. Shortly afterwards, the syndic of the islanders announced that a fresh attempt, made under favourable circumstances, had met with success, and he forwarded a specimen, which showed the rock to consist of a gneiss tolerably hard, except in some parts where it was decomposed.

The following mode of construction was therefore decided upon, viz., to bore holes 30 centimetres in depth, and one metre apart, all over the site of the intended edifice, and some other holes outside this limit, in order to hold the ringbolts necessary for craft coming alongside, and to fasten the shrouds. The object of the first set of holes was to receive wrought iron gudgeons, to fix the masonry to the rock, and to make the construction itself serve to bind the different parts and fissures, and thus consolidate a base the precarious nature of which gave rise to some misgivings.

It was proposed that in addition to these gudgeons others should be added, and strong iron chains introduced horizontally into the masonry, in proportion to its progress, so as to prevent any possible disjunction.

For the work of boring the holes, the services of the fishermen of the isle of Sein were called into requisition, since their calling familiarised them with all the rocks of the causeway, and they were in a position to take advantage of every favourable opportunity. After many difficulties, they accepted a contract, the Government agreeing to furnish tools and life-belts.

In 1867 they went vigorously to work, and hastened to avail themselves of every possible chance of working. Two men from each boat landed on the rock, and provided with their cork belts, lay down upon it, holding on with one hand and using the jumper or hammer with the other; they worked with feverish activity, the waves constantly breaking over them. One was carried off the rock, and the violence of the current bore him a long distance from the reef, against which he would have been dashed to pieces. However his life-belt kept him up, and a boat went to fetch him back to work. At the close of the season, seven landings had been effected, and eight hours of work accomplished, during which, fifteen holes had been bored in the highest parts of the rock. It was the first step towards success. In the following year greater difficulties were encountered, since it was necessary to commence on the point hardly above the surface of the water; but the experience gained was valuable, and a higher rate of remuneration gave additional encouragement to the fishermen; the season was favourable, sixteen landings were effected, eighteen hours of work accomplished, forty new holes bored, and they even succeeded in partially levelling and preparing the work for the first course of masonry.

The construction, properly so called, was undertaken in 1869. The galvanized wrought iron gudgeons, $0^{m},06$ square and 1 metre in length, were fixed in the holes, and the masonry was commenced with small undressed stone and Parker-Medina cement. In fact, a cement of the most rapidly hardening character was essential, for the work was carried on in the midst of waves breaking over the rock, and which sometimes wrenched from the hand of the workman the stone he was about to lay. An experienced sailor, with his back against one of the iron stanchions, was always on the watch, to give warning of such waves as were likely to sweep the rock, when the men would hold on, head to the sea, while it washed over them. On the other hand, when he announced a probable calm, the work went on with great rapidity. All the workmen were supplied with life-belts, as the fishermen had been, as well as with spikes, to prevent slipping. The conductor also and the engineer, who by his presence always encouraged the workmen, were similarly furnished.

Every opportunity presented by an exceptional state of the sea was embraced, and a small steam sloop, carrying the workmen and the quantity of materials for the work of a tide, started from the island so as to arrive in sight of the rock at about four hours of ebb. But there was not always the calm weather calculated upon, and the day was sometimes lost. When a landing was practicable, the stones and small bags of cement were landed by hand, and care was taken to dress the surface of the masonry before commencing a new course. It is unnecessary to add that the cement was employed pure, and mixed with sea-water.

At the close of the season of 1869, twenty-five cubic metres of masonry had been executed, and these were found intact the following year.

At the present date, the cubic contents of the masonry are $454^{m},85$, rising to a level of $2^{m},60$, above the highest tides. The success of the undertaking may therefore be looked upon as assured, and at this stage, the work may be expected to advance more rapidly.

Since 1871, Portland cement has been substituted for Parker, the resistance of the former to the decomposing action of sea-water being ascertained to be superior to that of the latter; and the stone-work at the foot of the building will be preserved by refilling the interstices, and perhaps by a continuous covering of the same material.

From experiments upon the cohesive qualities of the mortar and the stones found in the vicinity, it was observed that the amphibolic or hornblende rock of Kersanton was superior in this respect, as in many others, and it was therefore exclusively employed in the execution of the masonry. The facing stones are scappled, while those for the filling in are as they come from the quarry, and all are of small dimensions. The galvanized wrought iron gudgeons, tie-bars, and bands, are deeply embedded in the stone-work in order to prevent disjunction.

According to the project recently adopted, the light will be of the second order, with a flashing light, and the focus will be elevated 28 metres above the level of the highest tides. This limit might have been exceeded, so as to admit of a light of the first order, but for the insufficiency of the base, and it was necessary above all things to ensure the stability of the edifice. The solid part constituting the basement will be continued with the diameter of $7^{m},20$, up to the level of high tides, and with that of $6^{m},90$ for the three following metres. The limited extent of the rock necessitates these small dimensions. The interior diameter will vary from 3 metres in the lower to $3^{m},40$ in the upper part, by means of successive off-sets, and the thickness of the wall will diminish from $1^m,70$, level with the entrance door, to $0^m,80$ below the cornice of the capping. There will be eight stories in the edifice, one of which will be devoted to a sounding apparatus to indicate the position of the lighthouse during a fog.

The annexed table, while reproducing some of the figures already given, shows the principal facts relating to the works executed, commencing from 1867.

YEARS.	NUMBER		CUBE OF MASONRY EXECUTED		COST PER YEAR.	AVERAGE COST per CUBIC METRE.
	of landings.	OF HOURS on the rock.	per year.	per landing.		
1867	7	$8^h\ 00^m$	〃	〃	$8{,}000^f$	〃
1868	16	18 00	〃	〃	21,000	〃
1869	24	42 10	$25^m\ 05$	$1^m\ 04$	25 000	998^f
1870	8	18 05	11 55	1 44	26,336	2,289
1871	12	22 10	23 40	1 95	17,000	721
1872	13	34 20	54 55	4 20	40,000	727
1873	6	15 25	22 00	3 67	62,000	2,818
1874	18	60 10	115 30	6 41	71,800	623
1875	23	110 55	203 00	8 80	76,000	375
TOTALS..	127	$329^h\ 15^m$	$454^m\ 85$	$4^m\ 37$	$347{,}136^f$	745^f

This work was conceived and planned in what is essential by M. Léonce **Reynaud**, director of the Lighthouse service. In the first instance, it was carried on under the direction of M. **Planchat**, engineer in chief, and afterwards under that of M. **Fénoux**, engineer in chief, by MM. **Joly**, from 1867 to 1868, **Cahen**, from 1869 still 1874, and **Mengin**, from 1875. MM. **Lacroix**, principal conducteur, and **Probesteau**, conducteur, have been successively charged with the superintendence of the works.

It is to be regretted, since it would only be an act of simple justice, that to this list cannot be added the names of those brave sailors and Breton workmen, who, unconscious of their claims to admiration, have, by dint of energy and earnestness of purpose, ensured the success of an enterprise, bolder and, it might be said, more rash than any preceding undertaking of the same nature.

XLVII

TURRET AND CANDELABRUM

FOR PORT LIGHTS.

Two models on a scale of $\frac{1}{10}$.

The arrangements of this turret are such as to realise a mode of construction at once simple and economical, and offering at the same time great facilities for transport and erection.

It rests upon a cast iron plate in a simple piece, and is attached by five bolts either to masonry or to the framework of a jetty.

It consists of a riveted sheet-iron cylinder, $1^m,40$ in diameter and $6^m,40$ in length, with striated sheet-iron stairs inside, supported by a cast iron pillar or newel, and riveted to the cylinder by means of angle-irons. The cylinder and stairs form one, and are not taken to pieces. The length does not exceed the limit specified in the railway tariffs of carriage, and is easy to manage and raise, by means of a winch.

Cast iron flanges and brackets, bolted to the cylinder, support an open-work cast iron gallery with a wrought iron balustrade, and a cylindrical sheet iron cylinder which carries the lantern. These complete the turret, properly so called.

The lantern is in bronze, it has cylindrical glasses, and is surmounted by a copper cupola.

At the base of the candelabrum, upon which is placed the apparatus for lighting, a revolving cast iron, landing place enables the keeper to clean the glasses without obstructing the passage of the stairs.

The cylinders being placed in position by means of a winch, the other parts, which are comparatively light, are easily raised by a tackle suspended from a beam projecting from the top and firmly attached to it by ropes.

The weight of the turret proper, the foundation plate and upper part, is about 6,500 kilogrammes.

The cost of the construction, including the lantern, glasses, and candelabrum supporting the apparatus for lighting, is 9,200 francs, in Paris.

The candelabrum enables a port light to be placed at the extremity of a very narrow jetty, where it can be hoisted to a height of 8 metres during the night, and locked up in a sheet-iron cabin during the day, till the moment of lighting.

This cabin bears two uprights in sheet iron, at the top of which is fixed a pulley mounted in a cast iron block.

Two half-round wrought iron guide rods are held at the top by the side of the uprights by two iron arms, and at the bottom, by a table in sheet and wrought iron which projects outside the cabin.

The apparatus is rolled on to this outer table, when it is necessary to hoist it, and is provided with ears which run on the iron guides during its ascension.

The front of the cabin facing the service table and the guides is pierced with an aperture sufficiently large to admit the lantern, and is closed by two shutters opening inwards.

Above this aperture, and inside the cabin, is the little cast iron winch, with brake, round which winds the chain for hoisting.

An interior table receives the apparatus when not in use, and is terminated by a cast iron turning table or plateau, intended to facilitate clearing.

The opposite side of the cabin is pierced by an aperture, with a door fastening with lock and key.

The interior is lighted by two lateral windows and by a round hole, pierced in the roof, and glazed. This allows the ascent of the lantern to be watched, and also to be assured that it is lighted.

The weight of the cabin is about 1,000 kilogrammes, and the price, all accessories included, 1,680 francs, in Paris.

These two little constructions have been adopted by the Lighthouse board of direction.

They were invented and are manufactured by M. L. Sautter, Lemonnier and Company.

M. Baillet, foreman.

XLVIII

LIGHTING APPARATUS.

1. *Apparatus for electric light.* — An intermittent light. at half-minute intervals, is intended to be produced by this contrivance, through the medium of electricity. It comprises a fixed light apparatus, $0^{m},50$ in diameter, illuminating three fourths of the horizon, around which cylinder composed of sixteen vertical lenticular elements, $0^{m},62$ in diameter, revolves once in eight minutes.

In the profile of the fixed light apparatus, the central dioptric part occupies vertically an angle of 76 degrees, which is greater than in the former profiles. This arrangement has been adopted in order that the luminous radius should meet the last dioptric element, at the same angle as the first catadioptric ring, and suffer no more loss by reflection in the one case, than in the other. The apparatus being placed in an elevated position, the profiles of the different parts, except those of the two lower catadioptric rings, have been calculated so as to direct the emerging rays 30 minutes below the horizontal plane. In the calculation of the two lower rings, this angle has been carried to 3 degrees for the last ring but one, and to 5 degrees for the last, so that the light should be visible for a short distance, that is to say, to a navigator in a position below the diverging collection of rays emitted by the remainder of the apparatus.

The 16 vertical lenses are close to each other, and each is composed of a single element; about $0^m,12$ in breadth, the curve of which has been calculated so as to give, with the electric light, a horizontal divergence of 3°,7. According to this arrangement, the light appears for 5 seconds, and the interval between the end of one flash and the commencement of another is 25 seconds.

The maximum intensity of the light approximates to nearly 60,000 burners, supposing an electric light with 200 burners at the focus.

2. *Apparatus of the third order.* — This presents a type entirely new. For the space of half a minute it is a fixed white light, while during the other half, eight flashes succeed each other at intervals of 3 $\frac{3}{4}$ seconds. The difficulty of giving to each light a distinctive character is augmented in proportion to the increase in the number of lighthouses. Into the programme of 1825, the Commission had only admitted three different characters for lights of the first order, viz. the fixed light, the intermittent, with minute intervals, and the intermittent with half-minute intervals. They had also retained the system formerly in vogue in the vicinity of Havre, consisting of two lights, side by side. One character, that had been previously reserved for lights of the second and third order, has been latterly assigned to some of the first; this is the light varied by flashes, at intervals of 3 or 4 minutes. Another system recently adopted, under the name of flashing light, consists in flashes rapidly succeeding each other, at intervals of a

few seconds. Finally, the aid of colour has been called in to form new distinctive characters, such as the fixed white light, varied by flashes of red; the intermittent light with alternate flashes of red and white, and the intermittent, with two white flashes succeeding one of red. Other combinations have also been adopted for lights of the second and third order, as, the fixed red, the intermittent red, the light alternately white and red, intermitting or not. This enumeration shows how much ingenuity has been taxed in order to vary the appearances of lights.

The choice of a distinctive character for the new light upon the rock of le Four, in the vicinity of Brest, gave rise to some perplexity. On that coast the lights are very numerous, and the greater part of the characters in use are found there. It must also be remarked, that it is not sufficient to create a difference between two lights, by means of a merely subordinate detail; on the contrary this difference ought to be strongly defined, so that no chance of confusion may exist.

This conviction induced the adoption of a combination never before applied, viz. the light described above as alternately fixed and flashing.

The lighting apparatus is of the third order, and is 1 metre in diameter. It consists of two different parts, each occupying half the circumference. The first part is an ordinary fixed light apparatus, while the second comprises eight complete annular panels, each occupying $\frac{1}{16}$ of the circumference, and calculated to produce eight flashes of light.

The revolving part is placed in the socle, and is fitted with the machinery requisite for producing a rapid movement. The rotation of the light of le Four is accomplished in one minute.

The lamp has a clockwork movement, and a burner with three wicks, arranged to burn mineral oil.

The lamp has an intensity of 14 carcel burners; that of the fixed light is 220, and that of one of the flashes attains 930 in the axis.

The price of the apparatus, including lamps and machinery, is 17,300 francs.

3. *Apparatus of the second order* (a drawing of the entire apparatus and an annular panel of $\frac{1}{8}$). — This apparatus is intended for the lighthouse of Pilier, situated at the embouchure of the Loire, the tower of which has just been reconstructed. The description of light adopted in 1829 is still employed, viz. a fixed light varied by flashes at intervals of 4 minutes. This apparatus consists of a fixed light, the two opposite sectors of $\frac{1}{8}$ of the horizon are replaced by complete annular lenses, and it revolves once in 8 minutes. In order that the two kinds of lenses may join properly, and that one common rack should serve, the focal distance, which is $0^{m},700$ for the lenses of the fixed light, has been reduced to $0^{m},647$ for the annular lenses. The focal lamp has five concentric wicks, instead of four, the usual number for lamps of the second order, because the colour of the light being red in certain directions, it was considered expedient to increase its intensity.

Several new arrangements are presented by this apparatus, some of which are applied for the first time.

1. In the central or dioptric part, the joints separating

the elements, and consequently the lower sides of these elements, instead of being horizontal, are inclined in the direction of the refracted ray. Several advantages result from this system : it dispenses with a triangular part of the glass, which is of no use, and thereby lessens the weight; the loss of light occasioned by the horizontal joints is greatly reduced; the exterior angles of the lenses are not so sharp, and consequently less fragile, and in addition, they do not project so much, which allows a greater height to the dioptric lens.

2. The central or dioptric lens embraces a vertical angle of 76 degrees, while in the former profiles this angle was only about 60 degrees; so that the height is increased from $0^m,85$ to $1^m,10$. By this means, the luminous rays meet the last dioptric element at the same angle as the first catadioptric ring, and suffer no more loss by reflection in the one case than in the other.

3. The profile ordinarily used had been calculated for a burner with three wicks and a diameter of 74 millimetres. But in the case of a burner with five wicks and a diameter of 110 millimetres, the lower elements of the dioptric lens and the lower catadioptric rings, constructed according to the former profile, emit rays which are no longer parallel to the optical axis, because the portion of flame left visible by the base of the burner is nearer the lens than in the case of a burner with three wicks. To obviate this defect, the burner was arranged in divisions or stages, by placing each wick 2 millimetres below the one preceding it. This plan diminishes neither the regularity nor the intensity of the flame, and the portion visible from each of

the lower lenticular elements is somewhat augmented. Besides, for each of these lower elements, a particular focus has been calculated, taken in the most brilliant line of the visible part of the flame, instead of being in the axis of the lamp. Similar arrangements might be advantageously adopted in many instances.

4. The central lens and the lower rings are contained in the same frame. The upper rings are mounted in a second frame, and separated from the first by a metal cross-piece. In the annular lenses, this cross-piece takes the form of an arc of a circle, having, like the rings, its centre on the optical axis, and it follows that the rings may be left intact, instead of cutting them as was formerly done.

5. The lamp in the focus of the lens exhibited offers some peculiarities of arrangement, due to M. Dénéchaux, engineer at the central dépôt of lighthouses. The skin valves and the leather claks have been replaced by ordinary pistons and metallic claks, the former being liable to frequent derangement. This method has given satisfactory results in some experiments, but has not yet received the sanction of practice.

With mineral oil lamps with five wicks having an intensity of 36 carcel burners, the fixed light apparatus produces an intensity of 640, and the annular lenses give a brilliancy of 5,000 burners.

4. *Twinkling catoptric light.* — Many lights of direction having to illuminate an angular and limited space only, are provided with a simple parabolic reflector. These are fixed lights. But in certain cases it is possible to con-

found them with lights in the vicinity, and even with lights on board ships at anchor. This difficulty has been overcome, without changing the apparatus, by means of a screen, passed rapidly and at equal intervals before the reflector. This system was applied for the first time, in 1865, to the lighthouse of Patiras (Gironde), and mariners having expressed themselves satisfied with the results, it has been employed at various points of the coast, since it possesses the double merit of being at once characteristic and economical.

The apparatus exhibited consists of a parabolic reflector of $0^m,50$ aperture, and a vertical screen to which a small revolving mechanism imparts a circular motion.

The light is fixed, but varied by very short eclipses succeeding one another at an interval of four seconds.

5. *Catoptric apparatus for a light of direction.* — This apparatus consists of a parabolic reflector, $0^m,50$ in breadth, and is lighted by a mineral oil burner with two wicks. There is no mechanism attached to the reservoir, as the oil ascends to the burner by the effect of capillary attraction. The form of the reservoir is that of a cylinder $0^m,20$ in diameter, which is placed behind the reflector, and communicates with the burner by means of a bent tube fitted with a three way cock. Its contains $3\frac{1}{2}$ litres up to 4 centimetres below the burner. The consumption being at the rate of 175 grammes per hour, the lamp can burn for sixteen hours, during which time the level of the oil lowers about 10 centimetres. The whole apparatus is established on a circular iron plate, fitted with rollers, and capable of being turned, in order to facilitate the

working. An iron set-bolt holds it in the position required. The reflector is fixed to the side of the lamp by a hook, which also supports the obturator by means of a rod.

The luminous intensity of the lamp is equal to about 6 $\frac{1}{2}$ burners; that of the reflector equals nearly 400 burners in the axis, and it diminishes from each side to an angular distance of 17 degrees.

6. *Apparatus for temporary light.* — This is intended to serve provisionally, during the repairs of an existing lighthouse, or in the interval previous to the definitive establishment of a new lighthouse. The arrangements are such as to admit of producing at discretion the different characteristics of coast lights.

It consists of a fixed light apparatus, $0^{m},375$ in diameter, capable of illuminating three fourths of the horizon, and a drum or cylinder with eight vertical lenses, $0^{m},50$ in diameter. The lantern is circular and has an exterior diameter of $0^{m},81$. The pedestal, $0^{m},45$ in diameter, contains a mechanism for imparting a rotary movement to the drum. The dimensions of the different constituent parts are upon a scale as moderate as possible, to facilitate carriage and to enable it to be mounted upon the exterior gallery of a lighthouse under repair, or upon a temporary frame-work.

The revolving mechanism is capable of giving three different degrees of speed to the cylinder, and this is effected by disconnecting gear. The vertical lenses slide into the grooves of the frame, so that they can be taken out or put in, according to the character of the light required. They are formed of two parts superposed, each of which is furnished with a little frame, into which a coloured glass can be inserted if necessary. The focal lamp has a lower reservoir without mechanism, and a burner with two wicks for mineral oil. It carries a plain or coloured glass chimney, according to circumstances, and can be replaced by a lamp with one wick, if only a moderate intensity is required.

With this apparatus can be produced:

A fixed white or coloured light, by removing all the vertical lenses the mechanism also, and placing a plain or coloured glass chimney upon the lamp.

An intermittent light, with minute or half-minute intervals, or scintillant light, by retaining all the vertical lenses and causing the machinery to move at one of the three degrees of speed;

An intermittent light, with alternate flashes of white and red, or red and green, by placing red or green glasses before a certain number of lenses, in the order indicated by the character of the light;

A fixed light, varied by flashes preceded and followed by eclipses, by retaining one of the vertical lenses, or several equi-distant from each other, and by adopting one of the three degrees of speed according to the time necessary to produce the interval between the flashes;

A fixed light, varied by flashes without eclipses, by removing half of each of the vertical lenses, and adopting one of the three degrees of speed.

The luminous intensity of the lamp with two wicks being equal to 6 $\frac{1}{2}$ burners, that of the fixed light equals 40, and that of the flash, 200 burners.

Numbers 2, 3, and 4, were executed by MM. **Henry-Lepaute.** The electric light apparatus was set up by MM. L. **Sautter**, **Lemonnier** and Company. The temporary light by MM. **Barbier** and **Fenestre.** All these gentlemen are lighthouse constructors in Paris; number 5 was made by M. **Luchaire**, constructor of lighting apparatus, in Paris.

The plans of these apparatus were drawn up by M. Émile **Allard**, engineer in chief « des Ponts et Chaussées », under the direction of M. Léonce **Reynaud**, inspector general.

The glass comes from the manufactory of Saint-Gobain.

XLIX

LAMPS AND APPLIANCES

FOR

THE ILLUMINATION OF LIGHTHOUSES WITH MINERAL OIL.

Up to a comparatively recent date, the lighthouses of France, like those of most other countries in Europe, were illuminated by colza oil. But when mineral oils began to come into general use, the French government hastened to profit by the advantages offered by this new combustible. From 1856 various trials were made with shale oil, and the results were satisfactory in lamps with one wick. In 1865 this oil was used in almost all the beacon lights on the coast, but its employment in lamps with several wicks was interdicted, on account of the inflammable nature of the vapour, when, in 1868, captain Doty, an American citizen, brought into notice a lamp burner with four wicks, in which he burned mineral oil. He introduced, at the same time, a product called Scotch paraffine oil, which possessed a valuable advantage, in as much as the vapour emitted therefrom only became inflammable at a temperature of 60 or 70 degrees centigrade, while in point of luminous intensity the results were excellent. After a series of experiments, prosecuted at the central Dépôt and in some lighthouses, this oil was generally adopted, and introduced into all the lighthouses on the French coast, with the exception of the floating lights, which continue to burn colza oil. Latterly, some French manufacturers have succeeded in obtaining products fulfilling the same conditions as paraffine oil, and which appear to be, in some respects, even preferable, while they are lower in price. Since the 1st January last, the mineral oil employed in the lighthouses of France, has come from the manufactory of M. Deutsch, near Paris, and its cost is 79 centimes per kilogramme, delivered at its destination.

The adoption of this new light producing element was accompanied by a remarkable diminution of expense, and it was considered expedient that a portion of the money thus economised should be employed, for the interests of navigation, in augmenting the luminous intensity of the various apparatus. This idea was carried out, and the lamp burners in the different orders of lighthouses were enlarged so as to receive another wick, and advantage was taken of the necessity of reconstructing them, to inaugurate a uniform system of wicks, by giving the same diameter to those of each row, commencing from the centre.

The burners exhibited have from one to six wicks. Five are allotted to the five orders of lights, while the burner with six wicks is reserved for exceptional cases. The exterior diameter of these burners increases $0^{m},02$ from $0^{m},03$ to $0^{m},13$. Each wick is contained between two thin copper cylinders $0^{m},005$ apart, and is separated from the next wick by an annular space of $0^{m},005$, to allow the passage of a current of air, the thickness of the metal being taken from the side of the wick. The average diameter of the wicks thus varies regularly from $0^{m},025$ to $0^{m},125$.

The burners with one and two wicks can be employed in ordinary lamps at a constant level, such as the two models exhibited by the side of the other burners; but they are often used in lamps having a lower reservoir without mechanism, and in which the oil ascends by capillary attraction. The first lamp of this kind was called the Maris lamp, from the name of the constructor, and it has been successively modified and improved at the Lighthouse Dépôt. The one in use at the present time, and of which two models are exhibited, consists of a cylindro-conical reservoir, placed in as close proximity as possible to the mass of oil in the top of the burner, without obscuring the luminous rays sent by the flame towards the lower rings of the optical apparatus. This reservoir contains 12 decilitres for lamps with one wick, and 3 litres for lamps with two wicks.

The burners that have from three to six wicks are used in the old lamps having a clockwork movement or an inside weight. The lower part of each burner is screwed on to the tube by which the oil ascends. The oil then reaches the small shallow cylindrical reservoir that forms the bottom of the burner. In the lamps which formerly burned colza oil, this reservoir communicated directly with the annular envelopes of the wicks, by means of vertical tubes, and the superfluous oil flowed over the burner and down into the body of the lamp. This system cannot be applied to mineral oil, the level of which must be kept $0^{m},04$ or $0^{m},05$ below the top of the burner. For this reason

M. Doty had adopted a different combination. A large oil reservoir, in which the level was permanently maintained by the ordinary contrivance known as Mariotte's vase, communicated with the burner by a tube that could be placed at a greater or less distance, and of which the top was fixed at the desired height above the constant level. This arrangement gave fair results and suited very well for experiments, but was evidently inadmissible in a practical point of view. M. Doty then entertained the idea of adapting to the ordinary lamps a lateral tube communicating with the burner, and open at the upper part to a proper level. The superfluous oil flowed through this orifice, and returned into the body of the lamp by a tube surrounding the first one. But the sole object of this lateral appendage being to maintain the constant level, it might be advantageously replaced by any orifice in the interior of the burner, affording an outlet for the oil at the desired level. The first lamps were therefore made with a tube placed in the axis of the current of interior air, communicating at the bottom with the interior of the burner, and open $0^m,04$ or $0^m,05$ lower than the top. These burners gave good results in the experiments at the Dépôt, and were applied in several lighthouses. It was admitted that they acted well, so long as the mechanism of the lamp was regular in its movement, but if the slightest irregularity occurred, or any inequality presented itself in the pump valves, then the ascent of the oil was subjected to variations more or less abrupt, and these variations had a very appreciable action upon the flame, which then became difficult to regulate. To obviate this inconvenience, it was necessary to cut off the direct communication by which the oil ascended to the wicks, and to make it pass first by a lateral appendage disposed so as maintain a constant level. M. Dénéchaux, principal conductor, performing the duty of resident engineer, invented the arrangements of this appendage which consists of three tubes placed close together, open at the top, and surrounded by a covering a little higher. The bottom of the central tube communicates with the little reservoir before mentioned; the oil, having no other issue, ascends by this tube, and falls from the top into the second tube, which takes it to the burner, in this manner filling the interior up to the level of that in the lateral appendage. Now as the quantity of oil furnished by the lamp, exceeds the consumption, the superfluity flows into the third tube, over a waste pipe, a little higher than that by which the oil reaches the burner. This third tube carries the overflow oil to the large reservoir of the lamp, and also receives, by a small lateral pipe, the droppings of the cup which forms the base of the burner. A horizontal disc $0^m,020$ in diameter surmounts the central air-tube which is between the burner and the chimney at a distance of $0^m,017$ to $0^m,023$, according to the size of the burner. On this exterior cylinder the chimney-holder slides. Satisfactory results are obtained from burners thus constructed. The flame is easy to regulate and the form remains steady without being subject to oscillation.

Bubbles of air that may have been drawn in by the oil escape by the lateral tube, and no longer interfere with the regularity of the flame. Supposing that, from some cause or other, the mechanism of the lamp be momentarily deranged, the flame will not be immediately extinguished, since the lateral appendage forming a reservoir supplies for some instants the oil necessary for combustion, and allows the accident to be remedied. Another advantage of this system is, that the superfluous oil no longer passes into the air tubes, thereby diminishing the section, and not having been in contact with the wicks, it has lost nothing of its quality, and differs in no respect from the reservoir oil with which it mingles.

It may be useful to remark that all the lamps, with the exception of those which have a lower reservoir without mechanism, are arranged to burn colza oil in case of need, or if any cause should again necessitate its use in a lighthouse.

This result is attained by raising to a proper height the reservoir of the uniform level lamps, by means of a notch in the covering, and for lamps of the three first orders, by closing the upper orifice of the lateral appendage, as well as the tube by which the overflow oil descends to the reservoir; this obliges the oil to ascend to the top of the burner, and to overflow.

The following table enables a comparison to be instituted between the former system of lighting, and that used at the present day. These figures show the advantages derived from the use of mineral oil in France, both as regards the interests of navigation, and those of the public Treasury.

		1st ORDER.	2nd ORDER.	3rd ORDER.	4th ORDER.	5th ORDER.	TOTAL.
Number of lights		42	6	81	33	254	
Consumption of mineral oil	per lamp and per hour.	1^{k}000	0^{k}645	0^{k}370	0^{k}175	0^{k}055	
	for all the lights and per year (4,000 h.).	168,000^{k}	15,480^{k}	45,880^{k}	23,100^{k}	55,880^{k}	308,340^{k}
Cost of mineral oil at 0^{f} 79 per kilog.		....	......	......	......	......	243,589^{f}
Consumption of colza oil	per lamp and per hour.	0^{k}760	0^{k}500	0^{k}175	0^{k}110	0^{k}060	
	for all the lights and per year	127,680^{k}	12,000^{k}	21,700^{k}	14,520^{k}	60,960^{k}	236,860^{k}
Cost of colza oil at 1^{f} 51 per kilog. (average price)		....	......	......	......	......	357,659^{f}
Intensity with mineral oil	per lamp	36	24	14,3	6,9	2,2	
	total	1512	144	443,3	227,7	558,8	2885,5
Intensity with colza oil	per lamp	23	15	5	3	1,6	
	total	966	90	155	99	406,4	1716,4

Thus, the cost, which is 243,000 with mineral oil, would amount to 357,000 francs with colza. There is therefore a diminution in the ratio of 1 to 0,68, i. e. nearly one third. To this must be added the difference in luminous intensity, the sum of which with mineral oil lamps is 2885 burners, while it would be only 1716. with colza lamps. The total intensity is augmented in the ratio of 1 to 1,68, i. e. more than two thirds. The total saving effected by the use of mineral oil is represented by $\frac{1,68}{0,68} = 2,05$, that is to say, that for the same outlay, between two and three times as much light is obtained.

It should also be remarked that, the diameters of the burners of each order having been increased, the horizontal divergence, and consequently, the duration of luminous appearances or flashes in revolving lights, is much greater than formerly. This augmentation is more than a fifth in the two first orders, and more than a half in the third.

A small mineral oil lamp with a circular wick, $0^{m},015$ in diameter, burning 20 grammes of oil per hour, and giving an intensity of nearly two thirds of a burner, is intended for the service of the keepers, and is employed in a few lanterns, where a great range is not required.

Two of the burners exhibited come from the works of MM. Barbier and Fenestre; two others are from the establishment of MM. Henry-Lepaute. The lamps and burners with one and two wicks were made by M. Luchaire.

By the side of the lamps and burners just described, is a series of seven plain chimneys which correspond to them. There are also the different coloured chimneys used in the Lighthouse service.

The instruments for testing mineral oils are contained in a box. They consists of two densimetres, an apparatus with a spirit lamp, to heat in a water-bath the oil about to be tested, and a thermometer to try the temperature of the oil. A light held above the orifice by which the vapours of the oil escape, indicates the moment when they become inflammable, and the thermometer shows the temperature of the oil. These instruments are furnished by M. Luchaire.

The oil-can used for mineral oil is cylindrical in shape, and movable round an axis nearly in the centre. It is usually held in a vertical position; the upper part is slightly conical, which allows it to be easily filled. When used, it is held in a slanting direction, and the cock and air-hole are both opened. Afterwards, the vertical position is resumed, and no leakage can occur from the cocks. This oil-can is made by MM. Barbier and Fenestre.

I.

BUOYS AND BEACONS.

Models.

Ordinary buoys. — The greater part of the buoys on our coasts resemble one or other of the types numbered 1 to 5. The first four represent beacon buoys, the fifth is a mooring or anchorage buoy.

Sheet-iron is more expensive than wood for the material, in respect of the first cost of placing, but it is more durable. Also the maintenance of sheet-iron buoys is less burdensome, and they are more easily adapted to different shapes.

The spherical form has been adopted for the submerged part of beacon buoys, because it is that which, the surface being equal, embraces the largest volume, and consequently reduces to a minimum the surface not visible. Provided that its centre of gravity is a little below that of the sphere, the float will remain steady, and this condition is easily fulfilled by means of properly calculated ballast. In short, the spherical form offers less resistance to the waves than the majority of those that have been adopted, and it is easily made at all the great iron works.

The upper part is in the shape of a truncated cone, the top of which is replaced by a disk or signal of various descriptions. The object of this appendage is to augment the range, and especially to give a distinctive character to the buoy, which may assist in discriminating the colours and inscriptions.

The body of the buoy is divided into two parts by a water-tight partition, so that if broken into, by the shock of a vessel, or injured so as to cause leakage, it would still float. A vertical tube, closed at the upper end by a screw plug, allows the water to be pumped out of the lower compartment. Two man-holes are formed in the buoy; one at the top, and the other in the water-tight partition.

The mooring ring, to which the holding chain is attached, forms part of the mass of forged iron that constitutes the bottom of the buoy. This is in the shape of a spherical cap, and to it are riveted the sheets of iron composing the lower part.

The ballast consists of several movable cast-iron plates, bolted solidly together. Its weight does not exceed 750 kilogrammes, in the heaviest buoys, and is reduced according to the depth of the water and the strength of the current. Once properly regulated, the buoy preserves an upright position in the ordinary state of the sea, and scarcely inclines to 45° under the action of the strongest winds and currents.

A wale in elm wood encircles it at the point of greatest diameter, which is nearly level with the line of flotation. This wale is for the purpose of protection against the shocks of floating bodies; also against possible injury during transport.

The forms of signal or sea-mark most generally adopted are the sphere, single and double cones with straight or curved lines, rectangles, and triangles plain, or variously grooved or hollowed, crossing each other at right angles.

The moorings usually employed consist of a mass of cast iron, of which the weight varies according to the power of the buoy, the nature of the bottom, and the violence of the currents. For small buoys, in places where the bottom is composed of sand, a weight of 300 kilogrammes has been found sufficient, while in some parts it is necessary to increase this figure to 3,000. These moorings are in cast iron, and take the form of caps, with the lower face slightly hollowed, for the purpose of causing them to adhere more firmly to sandy bottoms; some are on a square, others on a circular plane. In certain cases, they take the form of a mushroom anchor, specially for the stronger buoys moored on rocky bottoms. When it is a question of reducing as much as possible the swinging range of the float, or when the buoy is moored to a rocky bottom, where there are strong currents, recourse is had to a cross mooring of two anchors with one fluke. In the basin of Saint-Nazaire, the bottom of which consists of a floor of beton covered by a thin layer of mud deposited by the river, and where it was essential to avoid all projections, flat cast iron moorings were adopted for the anchorage buoys. The weight of these moorings is estimated at 5,350 kilogrammes, and the side rings allow them to be lifted when it is necessary to change their position.

A part of the chain, from 2 to 8 metres in length, according to circumstances, is fastened permanently to the buoy, and to the rest of the chain by means of a shackle. The shackle-bolt is elliptical in form, and is held fast by one or two conical pins, the heads of which are covered with lead. The swivel is no longer employed, being useless and liable to cause accidents, when the float is in the form of a solid of revolution.

The models exhibited were planned by M. Luchaire, ferblantier-lampiste in the Lighthouse service.

N° 1. *Bell buoy.* — The body of this buoy is surmounted by an iron armature, on which are fixed wooden laths 0^{m},01 in thickness, covered at the upper part by a sheet of iron. In the interior of the armature is a bronze bell with movable hammers, and on the top is fixed a sea-mark or signal, above which is a triangular prism fitted with mirrors. The covering does not reach to the feet of the uprights, in order to allow free passage to the waves. The mirrors are framed in bronze, and serve to reflect the rays of the sun, or of the adjacent lighthouse. The trunk of the buoy is 2^{m},43 in diameter by 1^{m},70 in height, and the top of the prism of mirrors is 4 metres above the line of flotation.

The sheet-iron of the lower part is 0^{m},009 in thickness, while that of the upper part and of the water-tight partition is only 0^{m},005. The ballast is 500 kilogrammes in weight, when the length of the chain does not exceed 10 metres, and the line of flotation is then about 0^{m},12 above the lower edge of the wooden wale.

The mooring chain is in wrought iron, 0^{m},034, and weighs 25 kilogrammes per metre out of the water.

The average weight of buoys of this kind may be reckoned at 2,200 kilogrammes with the shackle, ballast not included.

They cost about 2,300 francs, namely:

Sheet and wrought iron, 1,896 kilogrammes at $0^{f},90$.	$1,706^{f},40$
Cast iron for ballast, 500 kilogrammes at $0^{f},25$....	125 ,00
Bronze for bell, mirror framing and pump collar, 54 kilogrammes at $5^{f},50$....................	297 ,00
Wale in wood and laths......................	90 ,00
Painting................................	81 ,60
	$2,300^{f},00$

N° 2. *Ordinary buoy.* — This buoy is $2^{m},38$ in diameter by $3^{m},20$ in height of trunk. The top of the mark is 4 metres above the line of flotation.

The sheet-iron of the lower division is $0^{m},009$ in thickness, while that of the conical part and the water-tight partition is diminished to $0^{m},005$. The ballast is represented complete. It places the line of flotation $1^{m},15$ above the centre of the mooring ring, or $0^{m},13$ above the lower edge of the wooden wale, when there are 10 metres of riding chain.

The mooring chain is in wrought iron $0^{m},034$.

The average weight of this buoy is about 2,000 kilogrammes, not including the ballast, but with the shackle. The cost is nearly 2,000 francs, viz.:

1,840 kilogrammes sheet and wrought iron at $0^{f},90$.	$1,656^{f},00$
750 kilogrammes cast iron ballast at $0^{f},25$......	187 ,50
$4^{kg},20$ bronze for pump collar and air tube at 5^{f}, 50.	23 ,10
Wooden wale...........................	40 ,00
Painting, etc............................	70 ,00
	$1,976^{f},60$

This buoy is designated in the Lighthouse service as *ordinary buoy* n° 1.

N° 3. A buoy of the same shape but of smaller dimensions, being only 1^{m},82 in diameter by 2^{m},50 in height of trunk, designated in the service as n° 2. The sheet-iron covering is 0^{m},007 in thickness in the spherical part, and 0^{m},004 above.

The ballast complete is 150 kilogrammes in weight. The mooring chain is in wrought iron of 0^{m},030, and weighs 20 kilogrammes per metre. One of these buoys costs about 1,000 francs, viz.:

990 kilogrammes wrought and sheet-iron at 0^{f},90..	891^{f},00
150 kilogrammes cast iron for ballast at 0^{f},25.....	37 ,50
4^{kg},20 bronze............................	23 ,10
Wooden wale............................	30 ,00
Painting, etc............................	38 ,40
	1,020^{f},00

N° 4. *Small buoy.* — This is employed in all places where it is not necessary to have a very apparent shape, or where there is no great depth of water. It is 1^{m},50 in diameter by 2 metres in length, carries no sea-mark or signal at the top, and is in sheet-iron 0^{m},006 below, and 0^{m},004 above. It has no ballast, and the line of flotation is 0^{m},76 above the centre of the mooring ring, when there are 10 metres of chain, and this line rises 0^{m},005 per metre of chain within suitable limits.

The chain is in wrought iron of 0^{m},025, and weighs 14 kilogrammes per metre out of the water, and 12 kilogrammes in the water.

A man-hole is contrived in the conical part, and another in the water-tight partition which is placed in the height of the wale.

One of these buoys weighs 540 kilogrammes, and costs about 500 francs, shackle included.

N° 5. *Anchorage buoy.* — This buoy has been made in various sizes; the one represented by the model is 1^{m},80 in diameter, and the same in total height. It is formed of sheet-iron 0^{m},006 in thickness, the traction rod is 0^{m},06 in diameter and the tube which it traverses has only 0^{m},08 of opening; at the upper part there is a screw nut carrying a mooring ring, which is supported by the buoy, and presses the lower collar against the foot. There is no water-tight partition, and the man-hole is formed in the part submerged, in order to be protected from shocks.

The chain is in short wrought iron links 0^{m},032.

The weight of a buoy of this description may be reckoned at 775 kilogrammes, and its price at 600 francs.

Boat buoy. — Buoys in the form of a boat have the advantage of offering less hold to the current, and are easier to tow. The single inconvenience attending them is that they are more expensive.

They are only used at points where the currents are very strong, and where it is necessary to have very apparent signals.

The buoy represented by the model was executed in 1861, from the drawings of M. Leferme, engineer, by MM. Jollet and Babin, constructors at Nantes, and since that period has been placed to indicate the bank of la Lambarde at the embouchure of the Loire. It is 5^{m},35 in length, 3^{m},25 in its greatest breadth and 1^{m},50 in depth of hold. The top is more than 5 metres above the level of the sea. The sheet-iron is 0^{m},008 in thickness at the bottom and at the circumference, and 0^{m},005 at the upper part. The sheets are put together clinker fashion, on a slender framing formed of angle-irons 0^{m},05 and distant from each other 0^{m},625. A water-tight partition, perpendicular to the longitudinal axis, divides the float into two independent compartments. A sheet of iron, 0^{m},020 in thickness, is fixed vertically, following the same axis, by means of bands forming angle-irons on each side, and constitutes a powerful keel, the object of which is to keep the buoy constantly upright to the waves. A ring in front, to receive a warping or towing hawser, and four handles on each side to aid shipwrecked persons in taking refuge on the buoy, complete the float, which has no ballast.

The float carries a frame principally composed of eight wrought iron uprights, 0^{m},042 by 0^{m},022, which bend before they join, in order to sustain, below their point of junction, a bronze bell weighing 70 kilogrammes, and above, the rod of a sphere 1 metre in diameter, surmounted by a mirror with six sides, the summit of which is 4^{m},60 above the float. Thin bands of sheet-iron 0^{m},0015 surround the uprights, to which they are riveted, in order to render the whole more apparent, and to make the regulation inscription easily visible.

To fix the mooring chain, which is in wrought iron 0^{m},040, an eye is pierced under the float, in the triple thickness of the keel and the junction angle-irons, a little forward, but sufficiently near the extension of the axis of the armature, which is itself perpendicular to the water line, so that, by reason of the weight of the chain, the inclination of the frame varies very little with the height of the tide. This eye is fitted with a steel ring, and carries the bolt with a screw nut and pin, riveted hot, of a shackle which is followed by a large link, and then by the end of a chain 7 metres in length, $0^m,040$. This end of the chain must be considered as making part of the buoy, to which it is fixed on shore, and ought always to accompany it. At the lower part it carries a shackle which is itself linked to the tie. The bolt of this last shackle is elliptic, without projections, and held only by two conical pins, the heads of which are let in to the depth of a centimetre, and covered with lead driven by a heavy blow into a cavity in the shape of the trunk of an inverted cone. This system of mooring is combined so as to be able to place or change a buoy quickly and without difficulty, even in heavy seas, and is the only one which, during an experience of several years, has never failed.

This buoy weighs, everything included, 4,665 kilogrammes, and has cost, at the rate of $1^f,10$ the kilogramme of wrought iron, $5,131^f,50$.

Beacon buoy. — Several reefs of the coast of Morbihan are indicated by buoys planned upon an entirely different system. They have the merit of being comparatively cheap, and easy to tow, and they are well adopted to all those points where it is not necessary to have a signal that can be seen at a great distance.

The submerged part of the float is in the form of an inverted cone, $1^m,35$ in diameter and $2^m,16$ in height, finishing with a cast iron cap, joined to the sheet-iron by means of a wrought iron fretting. This cap is crossed by a square iron rod $0^m.04$, the extremity of which carries a shackle to receive the chain which is in wrought iron, of $0^m,03$.

The lower cone is connected by a cylindrical length, $0^m,25$ in height, with a trunk of a cone, joined at the top to another trunk elongated, which constitutes the signal of the buoy. These two parts are united by means of two angle-irons, between which is placed a partition, is made water-tight by an edging or washer of Indian rubber. The angle-irons are fastened with bolts, so that the signal can easily be separated from the buoy proper, when the latter requires inspection.

A hole in the lower part of the buoy serves to empty the water, and is stopped with a wooden peg. For the benefit of persons in danger of drowning, two handles are fixed to the sides.

The thickness of the sheet-iron, in the lower part, is $0^m,005$, and for the upper part or signal, $0^m,004$.

The total height of the buoy is 6 metres, and it rises $3^m,90$ above the surface of the water. Its maximum diameter, at the line of flotation, is $1^m,35$. The diameter of the signal is $0^m,57$ at the base and $0^m,34$ at the top.

This buoy weighs 800 kilogrammes, and cost 880 fr.

It was planned by M. Gouëzel, conductor «des Ponts et Chaussées» at Belle-Ile.

Beacon of Antioch. — The rock of Antioch forms a part of a very dangerous reef in the navigable passage that separates the isles of Ré and Oléron, and is situated about one mile north-north-east from the point of Chassiron.

Between 1811 and 1856, nineteen ships, including a corvette belonging to the State, were wrecked on this reef, which was only indicated by a simple iron beacon, not sufficiently apparent and frequently overthrown by the sea. The object of the present beacon was to remedy these deficiencies.

This rock is almost always very difficult of access, and the construction of a beacon in masonry would have been a long and costly affair, it was therefore decided to have recourse to an iron frame-work.

The beacon consists of four round standards in wrought iron, 0^{m},14 in diameter, following the angles of the trunk of a quadrangular pyramid, solidly connected with each other, and with a round central pile in wrought iron, 0^{m},10 in diameter.

The standards forming the angles of the pyramid, are 4^{m},86 apart, from centre to centre, at the lower part, and 2^{m},50 at the upper part, which is 7 metres above the rock.

They are surmounted by a construction of the same kind, in the form of a square and 3 metres in height.

Finally, the whole is terminated by a pyramid 2^{m},50 in height and crowned by a sphere 1^{m},30 in diameter.

For the purpose of rendering the edifice more apparent, all the upper part of the beacon is furnished with sheets of iron set in open work.

The rock of Antioch is composed of jurassic limestone, and does not possess sufficient firmness to hold the feet of the standards; it was therefore necessary to fix them, by means of wedges, in cast iron casings, let into the rock and laid in cemented stone-work.

The top of the beacon is 13^{m},80 above the rock and 10^{m},47 above the highest tides.

The central pile is fitted with ladder steps, which lead up to the base of the pyramid, in which a planking has been formed to serve as a refuge for the shipwrecked.

The cost amounted to 20,947^{f},90, divided as follows:

13,434 kilogrammes forged iron at 0^{f},95, including painting in red lead, setting up and taking to pieces at the iron works and carriage to a port in the isle of Oléron	12,762^{f},30
1,976 kilogrammes cast iron at 0^{f},60, everything included	1,185 ,60
Holes for uprights, erection and sundry expenses	7,000 ,00
Total	20,947^{f},90

The plan was drawn up and executed by M. de Beaucé, engineer, under the direction of M. Leclerc, engineer in chief « des Ponts et Chaussées ».

Most of the important beacons on the coasts of France are constructed in rough quarry stone with Portland-cement mortar.

SIXTH SECTION.

ELEVATION

AND DISTRIBUTION OF WATER.

LI

AQUEDUCT OF ROQUEFAVOUR

ON THE ARC.

(CANAL FROM THE DURANCE TO MARSEILLE.)

Model of the four first arches (left bank). — Scale $0^m,04$ (one twenty-fifth).

Model in wood representing the details of the various machines employed in the construction. — Scale $0^m,10$ (one tenth).

Drawing of the whole. — Scale $0^m,005$ (one two hundredth).

This aqueduct was constructed for the canal from the Durance to Marseille, and is 393 metres in length; the maximum height above the base of the socles is $82^m,65$, and the breadth at the top, $4^m.50$. There are three stages of arches, of which the first comprises twelve arches of 15 metres span: the second, fifteen arches of 16 metres; the third, fifty-three small arches of 5 metres.

Height of lower stage, from base of socle to first platform	34^{m},10
Height of intermediate stage, from one platform to the other	37 ,60
Height of upper stage, from second platform to top of parapet	10 ,95

The piers are strengthened by counterforts, the breadth of which they exceed by 1^{m},60 in the middle, and 2 metres in the lower stage. These counterforts extend from the socle up to the plinth of the upper stage, and are 3 metres in breadth, in the height of the first stage. Their projection is 0^{m},25 under the plinth, and 0^{m},65 at the springings of the arches of the second stage.

The piers have a diminution of 0^{m},005 per metre in the middle stage, and 0^{m},015 in the lower stage; they are 5 metres in thickness at the springings of the arches of the second stage, 6 metres at the springings of the first, 6^{m},57 at the top of the socle, and 7^{m},20 in the height of the socle. Their length is uniformly 4^{m},85 in the middle, and 5^{m},50 in the lower stage. The projection of the counterforts, in the direction perpendicular to the axis of the viaduct, increases from the top to the base, in the proportion of 0^{m},04 per metre from the top to the second platform, 0^{m},06 between the two platforms, and 0^{m},08 from the first platform to the base.

The dimensions of the piers and counterforts are as follows :

	BREADTHS		LENGTHS	
	of the pier.	of the counter-forts.	of the pier.	of the pier and the two counter-forts.
At level of springings of second stage of arches	5^m,00	3^m,00	4^m,50	5^m,80
Beneath string-course of 0^m,90 laid at this level	5 ,00	3 ,40	4 ,85	5 ,91
At level of first platform	5 ,25	3 ,65	4 ,85	〃
At level of springings of first stage of arches	〃	3 ,75	4 ,90	10 ,20
Beneath string-course of 1 metre extending to this level	6 ,00	4 ,00	5 ,50	10 ,56
At level of socle	6 ,57	4 ,57	5 ,50	13 ,60
In height of socle	7 ,20	5 ,20	6 ,10	14 ,20

The great arches are 1 metre in thickness at the key. The small upper arches are 1^m,05 at the key; their pillars are 4 metres in height, string-course included, 2 metres in thickness at the springings, and 2^m,05 at the base; the breadth of this stage between the heads is 4^m,50.

The trough is in brickwork, and has a breadth of 2 metres at the bottom, and 2^m,30 at the top by 2^m,40 in height with a gradient of 0^m,006 per metre.

A small gallery with a semi-circular arch of 3^m,30 span is formed immediately above the extrados of the first arches, and below the first platform; and gives access to the work at this level, either in the gallery or on the platform, by means of openings made in the piers, 1 metre by 2 metres. A similar gallery, 1 metre by 2^m,50, not arched, is also established above the second row of arches, and is comprised between their extrados and the level of the second platform.

For carrying the materials, uprights were fixed at the four angles of each pier, resting on two horizontal beams resting on brackets, and staged every three metres in the height of the pier. These uprights supported a scaffolding to which they were joined by a system of ties, braces and struts, and on the upper beams of this scaffolding, a movable winch was placed, capable of raising blocks of 6 cubic metres, weighing as much as 15 tons. In proportion as a pier was raised 3 metres, it was necessary to raise all the parts of the scaffolding, the supports and the crane. By means of four jack-screws with screws of $4^{m},50$ placed at the angles of the pier, this operation was safely accomplished in less than four hours, including the placing of the screws in position, each of them weighing more than 2 tons.

During their construction, all the piers were connected by a continuous railway, supported by a series of service-bridges between them. These were easily raised according to the elevation of the masonry. Two supplementary lines were also established; one on the level of the passage formed in the piers, and the other about 2 metres above it. They consisted of two beams thrown from one pier to the other, and strengthened by struts and uprights resting on the top of the centres. These arrangements allowed the piers and arches to be built at the same time, each division of the work having its lifting machinery, etc. independently of the other. By this method nearly 2,000 cubic metres of masonry per month were executed, and this work included the raising blocks of 8,000 kilogrammes to a height of 70 metres.

All the piers are constructed in rough stone; the beds and the perimeter of the vertical faces only are dressed, while the whole of each visible face remains rough. The total cube of the masonry is about 66,650 cubic metres, of which more than 50,000 are in rough stone.

The pressure at the base of the piers is $14^{\text{kg}},68$ per square centimetre.

The cost of the work, most of which was not performed by contract, amounted to 3,700,000 francs, about 177 francs per square metre of elevation.

This work was planned and constructed from 1841 to 1847 by M. de Montricher, engineer in chief « des Ponts et Chaussées ».

LII

BARRAGE AND RESERVOIR OF THE FURENS

FOR

THE SUPPLY OF THE TOWN OF SAINT-ÉTIENNE.

Model of the barrage. — Scale of $0^m,01$ (one hundredth).
Model representing a section of the two tunnels with their tops and working appliances.
Model. — Scale of $0^m,03$ (one thirty-third).

The town of Saint-Étienne is situated in the valley of the Furens, the water of which serves for various purposes. In the first place, a culvert conducts it from the springs to the town, but this supply is inadequate to the task of watering the streets and flushing the sewers, and the deficiency reaches to nearly 600,000 cubic metres per year. In the second place, the Furens puts in motion a number of manufactories which require a delivery of 350 litres per second, while the actual stream only gives from 80 to 100 litres in the dry summers, and does not exceed 500 litres on a yearly average. Also, the Furens may cause an inundation of the town of Saint-Étienne, but this rarely happens, and the discharge, even in the floods, does not exceed 15 cubic metres per second: nevertheless the bursting of a waterspout in the upper part of the valley, in 1849, caused an abnormal discharge which attained the exceptional figure of 131 cubic metres, the inundation of the town commencing at a delivery of 93 cubic metres.

The works undertaken had thus a threefold end in view : 1. to preserve the town from inundation, in case of the recurrence of phenomena similar to that of 1849; 2. to add to the quantity of water supplied to Saint-Étienne a supplement of 600,000 cubic metres per year; 3. to assure the regular working of the manufactories, and with this view, to maintain, as nearly as possible, a delivery of 350 litres per second.

This complex project has been accomplished by the construction of a barrage in masonry 50 metres in height, creating a vast reservoir in a narrow part of the valley of the Furens, called *le Gouffre d'Enfer*. This reservoir having absorbed a part of the former bed of the river, a new one was opened, capable of delivering 100 litres per second, under the name of a canal of diversion (canal de dérivation), and which after turning by the reservoir, joins the ancient bed of the river below the barrage.

The capacity of the reservoir is 1,200,000 cubic metres, from the bottom up to $44^{m},50$ of its height, and 1,600,000 cubic metres up to 50 metres, it therefore follows that the upper mass of water, $5^{m},50$ in depth, represents a volume of 400,000 cubic metres between the heights of $44^{m},50$ and 50 metres. Now, it has been ascertained that that part of the total volume of the flood in 1849, which corresponds to the discharge exceeding 93 cubic metres per second, was 200,000 cubic metres; therefore if the figure $44^{m},50$ be not exceeded in the height of the reserve, it will be possible to store up, in the higher level reserved for the case of inundation, a volume of water double that of the destructive excess caused by a waterspout like that of 1849. The flood once passed, and the delivery becoming less than 93 cubic metres, a culvert carries off all the water exceeding the height $44^m,50$. and at this height the floor of the culvert is laid, which discharges into the new bed of the Furens.

With respect to the 1,200,000 cubic metres of water contained in the reservoir below $44^m,50$, it forms a reserve which is held back so long as the delivery of the Furens exceeds 350 litres, and the town of Saint-Étienne uses it for consumption, or for manufacturing purposes, only when the delivery does not reach 350 litres. For this purpose, a second tunnel pierced in the rock and provided with two cast iron pipes $0^m,40$ in diameter, carries the water from the level of the bottom of the reservoir, and conducts it to a well, by means of cocks, so that the delivery can be modified at discretion, and the supply of the town and manufactories properly regulated. This well communicates, on the one part, with the new bed of the Furens, in which the volume of water to be delivered is determined by means of a sluice, and on the other, with the water conduit of Saint-Étienne, into which it delivers the quantity required. These arrangements allow such a volume of water to be drawn from the reservoir, as may be necessary for the benefit of the town, by its own conduit, and for the use of the manufactories, by means of the bed of the Furens.

Above the reservoir and the commencement of the diversion canal, a small barrage has been established, 12 metres in length and 5 metres in height, in which are pierced ten apertures $1^m,50$ in breath, each closed by an iron sluice. Below, the bed of the Furens is divided into two parts, each supplied by five of these sluices, capable of discharging 100 cubic metres, and of which the right hand bed takes the water to the diversion canal, and that on the left carries it to the reservoir. Water-marks placed above the barrage indicate the heights corresponding with the deliveries of 350 litres and 93 cubic metres.

The working of the sluices is arranged to meet every possible contingency. In case of an abnormal rise, and that the reservoir were full up to the height of $44^m,50$, the reservoir sluices would remain closed, and those of the canal open, so long as the delivery did not exceed 93 cubic metres, and all the water flowed through the bed of the Furens; but when the limit of 93 cubic metres is passed, which would be immediately ascertained by consulting the water-mark, the left hand gates would be gradually opened, so as to maintain the delivery into the canal at 93 cubic metres, and to direct the excess only into the reservoir in which the volume of water would then be stored that might otherwise have inundated the town. In the same manner these sluices are gradually closed in proportion to the diminution of the delivery, and are completely shut when it gets below 93 cubic metres, and the inundation of the town is thus avoided.

When the water is low, so long as the delivery is below 350 litres, the reservoir sluices remain closed, but if the delivery happen to exceed 350 litres, of which the second water-mark gives notice, the sluices are worked so as to maintain it at 350 litres only in the canal, and to direct all the excess into the reservoir where it constitutes a reserve. But the surplus water only, which is not required for the manufactories, is taken from the Furens, and the reserve thus created is restored with suitable care by the lower culvert, either to the town or to the manufactories. when the delivery gets below 100 or 80 litres.

The reserve of 1,200,000 cubic metres can be renewed twice during the year, and as the supplementary service of the town of Saint-Étienne does not exceed 600,000 cubic metres, there remains about 1,800,000 cubic metres to be utilised for the manufactories. This figure corresponds to an augmentation of the delivery from the Furens of 120 litres per second during six months in the year.

The barrage is 50 metres in height, $5^m,70$ in thickness at the top and $49^m,04$ at the bottom of the valley; in plane, it follows an arc of a circle having a chord of 100 metres, a versed sine 5 metres, and $252^m,50$ of radius. The two faces are continuous and nearly in conformity with the theoretical type, with a uniform pressure, studied by M. Delocre, resident engineer. They differ from this type, on the one hand, because curved profiles have been substituted for polygonal, and on the other, because in the upper part, the thickness has been greatly augmented, while in the lower it has been slightly diminished. These modifications were made in deference to the apprehensions excited by the possible action of waves and especially of ice, in a reservoir situated at an altitude of 800 metres, where the ice sometimes attains a thickness of $0^m,50$.

The following table shows the thickness at different heights, as also the maximum pressures when the reservoir is empty or full.

HEIGHT below THE TOP.	THICKNESS of the BARRAGE.	MAXIMUM PRESSURE, THE RESERVOIR BEING	
		empty.	full.
metres.	metres.	kilog.	kilog.
0,00	5,70	″	″
12,00	9,56	2,40	3,20
26,00	18,01	5,10	5,70
32,00	23,49	5,90	6,00
38,00	30,30	6,40	6,30
45,00	39,70	″	6,30
50,00	49,04	6,00	6,50

The profiles of the two faces once determined, as also the curve of the top in plane, the surfaces of the facings follow. They are two toric surfaces generated by the rotation of the normal profile round the vertical of the centre of the crown curve. The lower or down-stream facing is thus constructed, and in different places a certain number of square stones have been laid, projecting 0^{m},30, and arranged in quincunx. These are intended to support scaffoldings for inspection or repairs necessary in the future, and the up-stream facing is provided with large rings arranged for the same purpose, serving to make fast beams or planks, by the aid of ropes, or to moor boats in case of need.

All the masonry is let into the solid rock, in the bottom of the valley, as well as on the sides, and with this object, the exfoliated or badly adhering parts were cut away, and irregular redans or terraces have been contrived in which the mass of the barrage is solidly laid. All the masonry is in rough stone, with Theil lime. Horizontal courses have been avoided, and the stone-work is secured by strong bonders in all directions, in order to make of the barrage, as nearly as possible, a monolith. also with the view of permitting no solution of continuity, the two culverts have been tunnelled in the lateral counterfort.

Since it was first filled, the barrage has undergone no change, and the leakage is less than was expected.

The State contributed 570,000 francs to the expense of this work, and the town of Saint-Étienne 1 million francs.

Commenced in 1861 the works were terminated in 1866. M. **Graeff**, engineer in chief, directed the surveys and execution, with the assistance of MM. **Conte-Grandchamp**, resident engineer, who drew up the preliminary plans; **Delocre**, who made the theoretic surveys according to which the profile of the barrage was decided, and de **Montgolfier**, who was charged with the construction. (*Annals des Ponts et Chaussées*, 1866, 2nd volume.)

LIII

BARRAGE OF THE BAN,

CONSTRUCTED BY THE TOWN OF SAINT-CHAMOND

FOR THE SERVICE OF ITS FOUNTAINS.

Drawings on scales varying from $0^m,000\,075$ to $0^m,20$.

A barrage has been constructed on the Ban (a tributary of the Gier) with the object of storing in a vast reservoir the water necessary for the municipal consumption and industrial requirements of the town of Saint-Chamond.

This work is similar in many respects to the barrage of the Furens, established in the Gouffre d'Enfer, the model of which is exhibited. It only differs in respect to dimensions, the height being less, the breadth greater, the thickness reduced, and the pressure being increased to 8 kilogrammes per square centimetre instead of 6.

Excepting the parapets, it is also in ordinary stonework, and has been constructed with inferior ragstone.

The depth of the water is only 42 metres (instead of 50) and is limited by a side-weir of 30 metres, over which the excess discharges itself.

The capacity of the reservoir has not yet been accurately determined, but it may be estimated at between 1,700,000 and 2,000,000 cubic metres.

The water is brought by means of a tunnel, 60 metres long, bored in the rock which joins one of the extremities of the barrage. In this tunnel are laid two pipes 40 centimetres in diameter, let into the masonry, and each terminating in two safety contrivances. One of these is a valve, which can be shut so as to close the pipe, the other is a Herdevin cock. The pipes supply mutually, and discharge into an open channel in stone-work from which the water can be conducted at will, either to the river, or to a culvert in masonry which conveys it to Saint-Chamond.

A service-bridge was constructed to facilitate the execution of the works.

The cost amounted to 955,000 francs, of which the State paid 200,000, and the town of Saint-Chamond 755,000 francs.

In addition to this outlay, a sum of 450,000 francs was expended by the town, in the works of the aqueduct and in the distribution of the water, amounting altogether to 1,205,000 francs, at its own proper cost.

The sum now paid for the use of the water exceeds 83,000 francs, without exhausting the stock available. This amount has no reference to the water consumed for municipal services which are, of course, provided gratuitously. The various industries of the town have received an enormous and, so to speak, an unhoped for development. The water is remarkably suited for dyeing, and does not produce incrustation in boilers. At the present time it is being utilised for the hydraulic elevator of a considerable manufactory.

The success of an undertaking of this nature deserves to be remarked, seeing that it has been executed by a second rate town, and almost without the assistance of the State.

The only inconvenience worthy of notice is, that the water is easily disturbed by rain storms that follow the valley line of the higher lands, and the turbid water was carried directly to the pipes. An angle has been given to one of these pipes, a vertical pipe has also been placed so as to prevent this direct entrance, and to allow the water for consumption to be drawn from a higher level. Since this improvement the quality of the watèr has been much more satisfactory. A plan is also designed which will arrest the progress of the various matters brought down by the water.

From 1866 to 1869 the works of the barrage of the Ban was directed by M. Graeff, then engineer in chief, to day inspector general, and from 1869 to 1871, by M. Lagrange, engineer in chief, who succeeded him.

The works were executed under the immediate orders of M. de Montgolfier, resident engineer « des Ponts et Chaussées ».

LIV

ELEVATING MACHINES

FOR

THE SUPPLY OF THE CANAL FROM THE AISNE TO THE MARNE.

(WATER-WORKS OF CONDÉ-SUR-MARNE.)

Drawings on scales of $\frac{1}{320000}$ to $\frac{1}{2}$.

The canal from the Aisne to the Marne connects the navigable ways of the east of France with those of the north, and establishes a communication between the metalliferous basin of Saint-Dizier and the coal mines of the north of Belgium. The important interests promoted by this canal justify its being regarded as a line of communication of the first order.

Its length of 58 kilometres is thus divided:

Slope of the Aisne	39,487 metres.
Summit level	11,920
Slope of the Marne	6,628
Total	58,035 metres.

For its whole extent, the canal passes through an exceptionally permeable stratum of the white chalk formation, which required to be made generally watertight. Besides this disadvantage, the district through which it passes offers no adequate resources of supply at a convenient level. In order therefore to furnish the volume of water necessary at all times for navigation, it was necessary to take it from the Marne, and raise it to the summit level by the aid of powerful elevating machines.

This volume varies in the different seasons, but according to accurate experiments, and with the present traffic, it ought to attain 600 litres per second, during a great part of the year. But to ensure the efficient service of so important a line of communication, to meet the ever-increasing requirements of navigation, to allow, at no distant period, an increased depth of water, and finally, to shorten the time of filling, when some parts require emptying, it was indispensable to be able to supply much more than 600 litres, and the system established can deliver from the summit level 1,200 litres per second, which has to be raised to a height of from 27 to 28 metres above the level of the Marne at Condé.

The power necessary to perform this great amount of work was obtained by drawing a sufficient volume of water from the Marne, by means of a derivation canal which, starting from Châlons, descends to Condé with a slope of $0^{m},10$ per kilometre, slighter than that of the valley, and reaches the basin, formed in front of the water-works, at a level sufficiently raised above the river to create a fall, which varies from $6^{m},92$ during low water-mark to $3^{m},12$ in the highest risings.

The dimensions of this derivation enable it to convey as much as 13 cubic metres of water per second, and this quantity is taken from the Marne by the aid of a barrage formed in front of the town of Châlons, on the system Louiche-Desfontaines.

The level of the head water near the works is regulated by means of a weir constructed with vertical cast iron plates, enclosing a space into which the overflow water falls, and is carried off by vertical pipes, the ends of which dip into a sort of shaft or well, level with the lower channel, where its velocity is extinguished in eddies.

This novel arrangement, which may be usefully applied, has permitted the construction of a weir 40 metres in length, in a very limited space near the water-works, and whichs allow the water to fall from a height sometimes exceeding 7 metres.

The mechanical system of elevation consists of five Kœchlin turbines placed in a line, and 10 metres apart. By a wheel and pinion, each turbine moves a horizontal shaft, the axis of which is parallel to the line of the turbines, and $3^m,50$ higher than the normal level of the head water.

This shaft is supported by a frame formed of cast iron pillars, connected by a table and cross-braced by arcs of the same metal.

Right and left of the three central turbines, are arranged vertical double action pumps, of which the piston ascends and descends through the medium of connecting rods attached to crank pins at the extremities of the horizontal shaft of the corresponding turbine. Connecting shafts placed on the same level, and in continuation of the first, connect one system with another, and this is effected by coupling gear joining the crank pins.

The turbines at each extremity serve as a reinforcement, and are not connected with pumps like the three intermediate ones, but only take their share of the work when the crank is put in gear with the adjacent system. By means of the gearing thus effected, the almost constant resistance represented by the height of elevation of the water is surmounted, and it is always easy to put the turbines to the speed that agrees with the maximum of discharge, according to the variation of the disposable fall. Another method also presented itself of obtaining this speed, viz. to vary the resisting power, if occasion required, by giving to each pump a single or double action; and for this purpose it was only necessary to put a valve on the suction pipe corresponding to one of the faces of the piston.

The pumps are $0^{m},95$ in diameter, have a stroke of 1 metre, and can, without difficulty, work up to 9 and 10 strokes per minute. They are furnished with clack-valves, the arrangement of which constitutes the perfection of these elevating machines.

They consist of large rectangular valves pierced with eight oblong apertures, to which are attached small independent valves. They are mounted on a horizontal axis of rotation, proceeding from the clack-boxes by a stuffing box, and furnished with a small crank the pin of which is moved by a spring rod connected with the main shaft by transmissions and an eccentric.

This rod is arranged with springs, in such a manner that it can shorten or elongate according to the direction of the moving power, and its action first compels the clack-valve to descend, while in proportion as the stroke of the piston slackens, the discharge becomes less, and to shut at the moment the piston finishes its stroke. Directly the clack is down upon its seat, the spring rod ceases to act upon the pin of the small crank, changes its direction and allows the pin to slip into the fork at the end of the rod, where it slides smoothly until it touches the bottom. Then the rod recommences to act upon the clack-valve by attempting to raise it; the clack resists because it is held down by the pressure of the water, but the tension of the spring goes on increasing, and when the piston changes stroke and repulses the pressure of the ascending conduit, the clack-valve rises altogether, by the simple pressure of the spring.

The four spring-rods of the clack-valves are worked by a single eccentric.

A good valve should in the first place be light, and capable of being raised without effort, in order to permit the passage of a section of liquid equal to that of the pipes. Afterwards, when the piston is finishing the stroke, and the discharge of water is but small, requiring only a small section of pipe for its delivery, the valve ought to be sufficiently heavy to descend gradually towards its seat, and to rest there simultaneously with the termination of the stroke of the piston.

The application of the mechanism adopted to regulate the movement of the clack-valves has realised these conditions, and the results have been most satisfactory, since the pumps work up to 9 and 10 strokes per minute without any audible shock. The clack raises itself sharply, remains stationary during 93 hundredths of the stroke, and then falls back gradually on its seat.

As soon as the action of the spring-rods is suppressed, the movement of the clacks becomes abrupt, and they fall violently on their seats with shocks that would soon cause damage.

The supply water brought up by the pumps is raised to the adjacent hill by a force conduit formed by two rows of pipes 0^{m},80 in interior diameter, and is then discharged into an open channel which, after a course of 7,605 metres, brings it to the summit level.

The first cost of establishing this system amounted to the sum of 2,538,092^{f}75^{c}, divided as follows:

General expenses, superintendence	25,847^{f},87^{c}
Purchase of ground	368,190 ,06
Conducting canal	777,282 ,47
Discharge canal, weir, construction of machines, approaches and accessories	418,982 ,06
Ascensional conduit and channel	463,805 ,56
Elevating machines	483,984 ,73
Total	2,538,092^{f},75^{c}

On the other hand the annual working expenses are:

Salaries and wages		9,300^{f},00^{c}
Oiling and cleaning machines	5,039^{f},71^{c}	6,366 ,77
Packing of pistons and glands	513 ,00	
Firing and lights	514 ,06	
Maintenance of machines, canals and buildings		4,333 ,23
Total		20,000^{f},00^{c}

The Condé works have been in operation since October 1869, and supply a canal 58 kilometres in length, and on which the annual traffic is nearly 400,000 tons.

Numerous experiments have demonstrated that the object originally proposed has been completely and economically attained, and that not only are present requirements adequately met, but those of the future are amply provided for.

The product of the pumps in volume, *i. e.* the relation between the volume of water actually raised and that moved by the pistons, has been found to vary from 0,948 to 0,971.

The mechanical product in water raised, *i. e.* the relation between the actual work done by the system and the gross power furnished by the fall, amounts to 0,67.

In making a comparison between the actual working expenses and the volume of water raised in the second half of the year 1871, it has been calculated that the cost of delivering 1,000 cubic metres of water at the summit level was $1^f,08^c$, including the expenses of working-staff, oiling, cleaning, packing pistons, firing, lights, maintenance of machines, buildings, canals, etc.

The works were planned and executed under the direction of M. DURETESTE, engineer in chief, by M. GÉRARDIN, resident engineer « des Ponts et Chaussées ». The turbines were furnished by the firm of KOECHLIN. The pumps, connecting gear, and frames were made by M. CLAPARÈDE, constructor at Saint-Denis-sur-Seine, with the assistance of his engineer, M. BOULOGNE.

LV

DAM AND SIPHON-WEIR

OF THE RESERVOIR OF MITTERSHEIM.

(CANAL OF THE COAL MINES OF THE SARRE.)

Model representing section of dam and machinery of siphon, complete, on a scale of 0^m,025 (one fortieth).
Head of fetching[1] tube (amorceur), scale of 0^m,10 (one tenth).

The reservoir of Mittersheim supplies part of the canal of the Sarre coal mines, and is formed by a barrage in the valley of Naubach, where it constitutes a reserve of water having a surface of 261 hectares, and a maximum depth of 8^m,10 above the bottom sluice. Its total capacity is 7 millions of cubic metres, and of this quantity, 5,800,000 (equal to a volume of water 3^m,46) can be appropriated to the supply of the canal. Local circumstances require that the regulation level of the reserve should not be appreciably exceeded, and to ensure the perfect working of the weir, it has been necessary to reduce this limit to 0^m,05.

Dam. — The dam is 332^m,50 in total length, 8^m,82 in depth from the capping to the bottom plug or sluice, 6 metres in breadth at the top, and attains a maximum breadth of 36^{m},80 at the base, in the bottom of the valley.

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[1] The word «fetching» is employed in the case of a pump, when putting it in motion, and the circumstances being analogous, it is used here. (*Translator.*)

It is formed of a core or body of puddled earth, faced with masonry on the side of the water. The upper face presents a series of inclined walls separated by risbermes slightly sloping. Each wall corresponds to a height of 2^{m},50 by a breadth of 2 metres, and each risberme is 0^{m},60 in height by 3 metres in breadth, so that each bench gives a total height of 3^{m},10 and a horizontal breadth of 5 metres. There are one, two, or three benches according to the varying height from one profile to another, the lower bench being reduced to the dimensions required. The lower wall rests throughout on a foundation wall of varying height, but which everywhere penetrates to a bottom perfectly impermeable. Each is faced with masonry, 0^{m},50 in thickness at the top and 0^{m},70 at the base, which rests on a solid mass of beton. The risbermes are covered with stone paving, resting on a layer of beton, and have altogether a breadth of 0^{m},30. The upper wall is surmounted by a parapet, 1 metre in height, which protects the roadway against the waves.

The lower face of the dam presents, starting from the top, a first talus, 4 metres in height by 6 metres in breadth, then a horizontal bench 2 metres in breadth, and lastly a second talus 2 metres in base for 1 metre in height, going down to the natural bottom. This down-stream face is thoroughly drained by means of small channels descending from 1^{m},20 above the surface and filled with broken stone, and which discharge into a ditch at the foot of the dam.

Siphon-weir. — The regulating apparatus consists of two large cast iron siphons, $0^{m},70$ in interior diameter and $0^{m},022$ in thickness, communicating, by their ascending branch, with the reservoir at $3^{m},50$ below the reserve, and by their descending branch, with a discharge canal in which their orifice is kept under water by means of a small barrage. A small tube, $0^{m},15$ in diameter, is joined to each siphon and follows it throughout the whole of the bend. The lower orifice of this tube discharges into the same canal in which the end is also submerged, while the upper orifice opens into the reservoir exactly on a level with the reserve. This tube serves as a fetching tube, *amorceur,* for the siphon, and both are in permanent communication by means of a bent pipe, which connects their most elevated points. The head of the fetching tube is in cast iron, and is enlarged in the shape of a bell, expanding horizontally to an arc of a circle with a radius of $0^{m},80$. The two sides or *lips* (lèvres) of this head are profiled in such a manner that the lower lip presents to the water a horizontal line of overfall placed exactly at the normal level of the reserve. The upper lip is terminated by a rounded surface, tangent, in its whole development, to a horizontal plane passing at $0^{m},005$ above the lower lip. From these arrangements it results that the orifice of entrance is only submerged when the level of the water rises to more than $0^{m},005$ above the regulation reserve. The fetching (amorcement) is then effected in the following manner.

As soon as the water rises above the regulation reserve, it flows over the lower lip of the fetching tube; if this elevation attains $0^{m},005$, the entrance orifice of the fetching tube is submerged, and from that time, the air contained in the fetching tube, in the siphon, and in the upper tube, ceases to be in communication with the atmosphere. Then the water, in overflowing, draws the air from the small tubes and exhausts that of the siphon, and there ensues a diminution of pressure in the interior of the apparatus, the water ascends into the siphon, the fetching takes place, and finally the siphon works with increasing speed and discharge.

But another phenomenon prevents the pressure from indefinitely diminishing, and the delivery from indefinitely augmenting. The increasing velocity of the water entering the fetching tube creates, near its head, a partial depression in the plane of the fluid; this depression deepens in proportion to the augmentation of speed, and at last reaches and uncovers the upper lip of the orifice, thereby causing the admission of a certain quantity of air into the apparatus, a consequent increase of interior pressure and a diminution of speed. The same facts being successively produced, there results from these two opposing tendencies, a series of oscillations corresponding to the shutting and liberating the upper lip of the fetching tube. This state of agitation soon ceases, and a steady movement is established, during which there is a simultaneous issue of water and air.

When the rising of the water ceases, the level of the reservoir lowers, and the same phenomena are produced in an inverse direction; the siphon action stops, and the flow is arrested when the plane of the water returns to its normal height.

A few millimetres of elevation in the plane of the water, above the fetching tube, suffice to cause a marked increase of speed. The air ceases to enter, and the water escapes from the filled tube before this elevation has attained the permissible limit, $0^{m},05$. The discharge is then $0^{m},60$ per second, a quantity greater than the maximum delivery of the risings.

In order to exercise complete control over the apparatus, the head of the fetching tube has been disposed in such a manner that it can be raised or lowered in a single piece, by the aid of a regulating screw, the impermeability of the communications being assured by free dilatation joints. In addition, a small vertical iron valve gate has been placed in the head of the fetching tube, and it can move round a vertical axis, without ceasing to fit closely to the interior of the two lips, which allows the entrance aperture and consequently the discharge to be varied. The regulating is effected once for all, and the apparatus afterwards works automatically and requires no supervision.

The apparatus is double, and consists of two siphons, each of which is furnished with its own fetching tube with tube of communication. Thus each siphon forms a complete system, capable of working by itself while the other may require to be examined, repaired, or regulated.

All the pipes of the two siphons are contained in a square covered shaft, $6^{m},56$ square at the top; the thickness of the sides $1^{m},20$ at the upper part, increases by reason of an exterior tapering of one tenth, and of various interior counterforts serving as supports to the castings. In addition, two small semi-circular arches, 1 metre and $1^{m},60$ in breadth, shore up the tops of these sides in order to resist the thrust of the water, in the event of the shaft being emptied. The lower arch bears the heads of the fetching tubes and the siphons, while the upper one, perpendicular with the first, carries the lifting jack-screw of the bottom sluice and the covering slabs. Two culverts terminate in the centre of the well : the one, on the up stream side, is $1^{m},80$ span and $1^{m},80$ in rise below the key, and establishes a constant communication with the reservoir, so that the heads of the fetching tubes are always in still water; the other, on the down-stream side, is $1^{m},20$ by $0^{m},60$, and is kept closed by a cast iron sluice which can be worked from the top; it runs into the discharge canal and serves to empty the reservoir, in case of need. By opening the cast iron sluice and closing the first culvert, by means of small beams fitting in grooves contrived for this purpose, the well can be emptied, and all the parts of the siphons examined and repaired. Their ascending branches terminate in the reservoir by bell shaped circular orifices, and are fitted with gratings and clack-valves. The discharge culvert, into which the descending branches of the siphons and fetching tubes empty themselves, is closed on the down-stream side by a small barrage-weir, which retains the orifices of these pipes constantly under water.

The idea of employing fixed siphons as weirs for the regulation of a reserve was proposed by M. Girard and applied to the Southern canal; but large siphons have been employed there, which required considerable variations in the level of the reserve, to put them in motion or to stop them.

The peculiar conditions existing at Mittersheim, and the very restrained limit permissible, 0^{m},05, led M. Hirsch, engineer «des Ponts et Chaussées», to invent the special system of fetching tubes, which has completely fulfilled the purpose for which it was intended.

The works were planned and directed by MM. Bénard, engineer in chief, and Hirsch, resident engineer «des Ponts et Chaussées», from 1864 to 1866. Water was let into the reservoir in December 1866, and the siphons were put into action, for the first time, on the 12th January following.

SEVENTH SECTION.

VARIOUS OBJECTS.

LVI

COLLECTION OF PHOTOGRAPHIC VIEWS.

Twenty-two albums.

A series of albums containing views of the principal works executed on the different lines of communication in France, viz. :

		ALBUMS
SECTION I.		
Roads		1
SECTION II.		
Bridges		3
SECTION III.		
Railways	Northern Company. — Western Company	1
	Paris, Lyon and Mediterranean Company	1
	Southern Company	1
	Orleans Company	3
	Stations	1
SECTION IV.		
Interior navigation	Rivers	1
	Canals	2

SECTION V.

		ALBUMS.
Harbours	The Channel	1
	The Atlantic	1
	The Mediterranean	1

SECTION VI.

Lighthouses	1

SECTION VII.

Canals for water-supply	1
Water-works. Supply of Paris	1

SECTION VIII.

Public buildings	Various edifices	1
	The Opera	1

A part of this collection is reproduced in a work entitled : *the Public Works of France,* published in Paris under the auspices of the Ministry of Public Works. The first numbers of the work appear amongst the objects exhibited by this Ministry.

LVII

NATIONAL SCHOOL
«DES PONTS ET CHAUSSÉES».

More than a century has elapsed since the establishment of the School «des Ponts et Chaussées».

The pupils destined for the corps of *engineers «des Ponts et Chaussées»* are chosen exclusively from the Polytechnic School [1].

Independently of the engineer pupils of the State, the School «des Ponts et Chaussées» receives «élèves externes» either French or foreigners. After passing an examination, they are admitted to attend the courses of lectures, and to participate in all the interior studies of the School [2].

Finally, in order to assist candidates in passing the preliminary examination, a preparatory course of study has been instituted in the School, and is specially intended for young men desirous of being admitted as «élèves externes».

The instruction is entirely gratuitous for the «élèves externes» and for the *pupils of the preparatory course.*

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[1] See the Notice on the School «des Ponts et Chaussées» appended to the documents exhibited by this School.

[2] See, in the same documents, the conditions of admission for «élèves externes» and the conditions of admission to the preparatory course.

NOMENCLATURE OF THE COURSES OF LEÇTURES AND OF OTHER DOCUMENTS

PRESENTED TO THE UNIVERSAL EXHIBITION AT PHILADELPHIA.

I. — ADMINISTRATIVE DOCUMENTS.

(Documents collected in one volume in-8°.)

Notice on the School «des Ponts et Chaussées». Paris, 1873, 1 pamph. 8vo.

Decree of 13th October 1851, enacting the organisation of the Corps «des Ponts et Chaussées». Paris, 1867, 1 pamph. 8vo.

Decree of 13th October 1851, enacting the organisation of the School «des Ponts et Chaussées». Paris, 1867, 1 pamph. 8vo.

Internal regulations of the School «des Ponts et Chaussées». Paris, 1875, 1 pamph. 8vo.

School «des Ponts et Chaussées». — Admission of «élèves externes» to the courses of lectures at the School. — Decrees, orders, decisions. — Programme of attainments required for admission. Paris, 1875, 1 pamph. 8vo.

Preparatory courses for the School «des Ponts et Chaussées». — Decrees orders, decisions. — Programme of attainments required for admission. Paris, 1875, 1 pamph. 8vo.

II. — INSTRUCTION.

1. COURSES.

Programme of instruction at the School «des Ponts et Chaussées» drawn up by the Council of the School, and approved by the Minister of Public Works. Paris, 1875, 1 vol. 4to.

Bresse. — Course of applied mechanics delivered at the School «des Ponts et Chaussées» :

1st part. — Resistance of materials. Second edition. Paris, Gauthier-Villars, 1866, 1 vol. 8vo.

2nd part. — Hydraulics. Second edition. Paris, Gauthier-Villars, 1868, 1 vol. 8vo.

3rd part. — Calculation of bending moments in a beam with more than one span. Paris, Gauthier-Villars, 1865; text, 1 vol. 8vo; atlas, 1 vol. folio.

COLLIGNON (Édouard). — Course of mechanics applied to construction :

1st part. — Resistance of materials. Paris, Dunod, 1869, 1 vol. 8vo.

2nd part. — Hydraulics. Paris, Dunod, 1870, 1 vol. 8vo.

BAYLE. — Course of mineralogy and geology applied to construction. Paris, 1869-1874, 1 vol. 4to lithog. The first part is published.

GARNIER (Joseph). — Treatise on political economy, social and industrial; didactic exposition of the principles and application of this science. Seventh edition, Paris, Guillaumin, 1873, 1 vol. 12mo.

MANGON (Hervé). — Treatise on rural engineering. Paris, Dunod, 1875. — The 3rd volume, comprising agricultural machines, is published. Text, 1 large vol. 8vo; atlas, 1 vol. folio, 26 engravings. The other volumes will appear subsequently.

MANGON (Hervé). — Practical instructions concerning drainage, collected by order of the Minister of Public Works. Third edition. Paris, Dunod, 1863, 1 vol. 12mo.

BARON. — Notes taken by the pupils, at the course on the construction of roads. Paris, 1874-1875, 2 vol. 4to lithog.

MORANDIÈRE. — Notes taken by the pupils, at the course on the construction of bridges :

1st part. — General processes of construction. Paris, 1865-1866, 1 vol. 4to lithog.

2nd part. — Course on bridges, properly so called. Paris, 1866-1867, 2 vol. 4to lithog.

Morandière. — Treatise on the construction of bridges and viaducts in stone, wood, and iron, for roads, canals and railways. Paris, Dunod, 1875, text 4to, atlas folio. The two first parts are published.

Mary. — Notes taken by the pupils, at the course of internal navigation. Paris, 1868, 1 vol. 4to lithog.

Mary. — Appendix to the course of internal navigation. Practical details on the water supply. Paris, 1868, 1 vol. 4to lithog.

Jacqmin. — Steam engines. Lectures given in 1869-1870 at the School «des Ponts et Chaussées». Paris, Garnier, 1870; text, 2 vol. 8vo; atlas, 1 vol. 4to lithog.

Gérardin. — Course on steam engines, given at the School «des Ponts et Chaussées». Paris, 1876, 2 vol. 4to lithog.

Bazaine. — Notes taken by the pupils, at the course on railways. Paris, 1868-1873, 1 vol. 4to lithog.

Jacqmin. — The working of railways. Lectures given in 1867 at the School «des Ponts et Chaussées». Paris, Garnier, 1868, 2 vol. 8vo.

Jacqmin. — Railways during the war of 1870-1871. Lectures given at the School «des Ponts et Chaussées». Paris, Hachette, 1872, 1 vol. 8vo.

Chevallier. — Notes taken by the pupils, at the course on maritime works. Paris, 1871-1873, 1 vol. 4to lithog.

Voisin-Bey. — Course on maritime works, given at the School «des Ponts et Chaussées». Paris, 1875, 1 vol. 4to lithog. comprising chap. I and VIII.

Reynaud (L.). — Treatise on architecture:

1st part. — Art of building. — Studies on the materials of construction and the elements of edifices.

2nd *part.* — Composition of edifices. — Studies on the æsthetics, history, and present condition of edifices. Fourth edition. Paris, Dunod, 1870-1875; text, 2 vol. 4^{to}; atlas, 2 vol. folio.

Aucoc (Léon). — Conferences on administration and administrative law, given at the School «des Ponts et Chaussées». Paris, Dunod, 1869-1870, 2 vol. 8^{vo}. (Vol. III is in the press.)

Durand-Claye (L.). — Course on chemistry applied to materials of construction, natural water, soils and agricultural products.

1st *part.* — Chemical analysis. — Trial of materials of construction. Paris, 1875, 1 vol. 4^{to} lithog.

2nd *part.* — Properties of materials employed in construction. — Notes on lime and mortar. Paris, 1867, 1 vol. 4^{to} lithog.

2. CONFERENCES.

Amiot. — Summary of conferences on the electric telegraph. Paris, 1874, 1 vol. 4^{to} lithog.

Davanne. — Summary of conferences on photography. Paris; 1874, 1 pamph. 4^{to} lithog.

Coumes. — Summary of conferences on pisciculture. Paris, 1868, 1 vol. 4^{to} lithog.

Tronquoy. — Instructions on the execution of surveys of machines, and making the drawings clear. Paris, 1868, 1 vol. 4^{to} lithog.

Voisin-Bey. — Conferences on the maritime canal of Suez, given at the School «des Ponts et Chaussées».

Conte. — Conferences on the tunnel of the Alps, given at the School «des Ponts et Chaussées». 1 vol. 4^{to} lithog.

Marchal. — Conferences on the adjacent road service, given at the School «des Ponts et Chaussées». Paris, 1874, 1 vol. 4^{to} lithog.

3. VARIOUS DOCUMENTS.

Mangon (Hervé). — Laboratory and experimental workshop at the new Dépôt of the School «des Ponts et Chaussées». Paris, 1871, 1 pamph. 8vo.

Collection of drawings distributed to the pupils of the School «des Ponts et Chaussées». Paris, 1857-1875; text, 2 vol. 8vo; atlas, 2 vol. folio.

Catalogue of books composing the library of the School «des Ponts et Chaussées». Paris, National Printing Office, 1872, 1 vol. 8vo.

Catalogue of models in the galleries of the School «des Ponts et Chaussées». Paris, National Printing Office, 1873, 1 vol. 8vo.

4. REPORTS

PUBLISHED BY ENGINEERS SENT TO OTHER COUNTRIES ON SPECIAL MISSIONS.

Malézieux. — Public works in the United States of America in 1870. — Report of mission published by order of the Minister of Public Works. Paris, Dunod, 1873, text and atlas, 2 vol. 4to.

Malézieux. — English railways in 1873. — Report of mission. Paris, Dunod, 1874, 1 vol. 4to.

Dartein (**De**). — Study on Lombard architecture and the origin of the Roman-Byzantine architecture. Paris, Dunod, 1865-1873; text, 1 vol. 4to; atlas, 1 vol. folio.

Choisy. — The art of building amongst the Romans. Paris, Ducher and Company, 1873, 1 vol. small folio.

Croizette-Desnoyers (Ph.). — Notice on public works in Holland. Paris, Dunod, 1873, text and atlas, 2 vol. 4to.

5. PREPARATORY COURSES.

Collignon (Édouard). Course of analysis and mechanics, given at the School «des Ponts et Chaussées». — Notes taken by the pupils. Paris, 1876, 1 vol. 4to lithog.

Gariel. — Course of physics, given at the preparatory School «des Ponts et Chaussées». — Notes taken by the pupils. Paris, 1876, 1 vol. 4^to lithog.

Pillet. — Course of descriptive geometry and stereotomy, given at the School «des Ponts et Chaussées.» — Notes taken by the pupils. Paris, 1876, 1 vol. 4^to lithog.

LVIII

CENTRAL SOCIETY FOR THE RESCUE OF SHIPWRECKED PERSONS.

Trophy of safety contrivances.

Organization. — This society originated in a commission instituted in 1860, by the Ministry of Public Works, for the purpose of taking into consideration the necessary steps for the establishment of a complete service of rescue on the coasts of France.

Full particulars were obtained of the state of societies previously existing in some of our ports, as well as of the arrangements adopted in England. Those points of our coasts which figure most prominently in the annals of maritime disasters were also indicated, and the commission having made itself acquainted with the preliminary details, and with the conditions indispensable to the formation of a society, decided upon a plan of organization, at the same time expressing an opinion that the objects proposed would be more effectually accomplished by the agency of a private society, than by that of the Government, and that official action should be limited to assistance and encouragement.

About the same time, M. Gudin, a marine painter with just claims to celebrity, sought, with the aid of some friends, the best practical means of developing in France a system of rescue similar to that employed in England. M. Gudin was deeply moved by several deplorable calamities of which he had been an eye-witness, and the subject appeared to him of the greatest importance, not only on the score of humanity, but as concerning the honour of France that the coasts should no longer remain unprovided with the necessary appliances for rescue.

In this manner the elements of a private society were formed, and obtained the approval of the commission. Statutes and regulations were drawn up, and a decree, dated the 17th November 1865, recognized the public utility of the Central Society for the rescue of shipwrecked persons.

The first president chosen, was admiral Rigault de Genouilly, who, up to the time of his death, was indefatigable in his devotion to the work.

The Ministers of Finance, Marine, and Public Works, are honorary presidents of the Society, which is administered by forty members, of whom one fifth are renewed by annual election.

Nine members chosen from the council form a committee of management, and meet twice a month. One of these is appointed by the council to be the acting delegate. He represents the Society, signs orders for payment, and sees that the measures adopted are carried out. Two inspectors, naval officers, superintend the arrangement and opening of new stations, as well as the working of the service all along the coast.

Wherever a life-boat is placed by the Society, a local committee is instituted, which manages the service and corresponds with the central committee.

The cockswain of the boat is paid by the year, and the crew receive a certain sum every time the boat puts to sea, either for exercise or for the purpose of saving life.

Financial resources. — The pecuniary resources of the Society consist of the revenue of the reserved capital, annual subscriptions, voluntary gifts, and grants made by the chambers of commerce, the communes, departments or the Government.

Up to the 1st January 1876 the receipts amounted to 1,889,426 fr. 44 cent. The Ministry of Public Works also came to the assistance of the Society, and at the expense of the State ordered the construction of forty seven shelter sheds for the life-boats, and the expenses of these buildings may be estimated at about 400,000 francs.

Life saving apparatus. — These are of various kinds; the principal are life-boats, and the mortar apparatus.

Life-boats. — Numerous experiments were made with various types of life-boats, by a commission instituted at Cherbourg, and composed of officers and engineers of the navy. These trials resulted in the selection of the average model adopted in England by the *Royal National Life-boat Institution.*

This boat is manned by twelve men, including the cockswain and mate, and is provided with air boxes which render it insubmersible. A double bottom, fitted with valves, enables it to empty itself instantly when a wave breaks on board; if upset, it rights immediately, and it goes well either with sail or oars. Experience has fully justified the choice of the Society, and the coast populations now manifest the greatest confidence in these boats, the excellence and value of which they know by experience.

Mortar apparatus. — Greater difficulties presented themselves in the selection of this apparatus. Those used in various countries, and particularly in England, were the Manby mortar, and rockets of different sorts. The disadvantages of the mortar are, its weight, which renders it difficult to transport from one part of the coast to another, and the liability of the line to be broken by the abrupt tension produced at the departure of the projectile. The rockets are expensive, easily spoiled, and require to be managed by persons accustomed to their use. They have, however, afforded valuable assistance in many instances, and the French Society did not give up the idea of adopting them, after the introduction of some improvements. But something more practical was required, something that might be available at every point of our coasts, and with this view, the Society communicated with captain Delvigne, whose name was associated with some important works on weapons of war. The first question put to him concerned the possibility of employing the muskets of the custom house officers, for the purpose of discharging arrows carrying a light cord, in order to assist vessels stranded near the shore. This would meet the wishes of our revenue officers, for these excellent men were frequently witnesses of scenes of shipwreck, and were distressed beyond measure to see unhappy beings perish before their eyes, while they were powerless to render assistance.

Such was the origin of the simple and ingenious invention, which became the base of the system since adopted and successfully applied, since 1870, along the whole extent of our coasts.

In order to obviate the abrupt shock caused to the line by the projectile, at its departure, the idea occurred to M. Delvigne to attach the line to cord rings sliding along the arrow, from the point to the end, where they stopped. The inertia of the cord is thus gradually surmounted by the friction of the rings, and breaking is avoided. The trials made in presence of the commission were deemed satisfactory, and several revenue posts were immediately supplied with the apparatus, which enables a line to be fired a distance of nearly 60 metres, with a charge of powder weighing 3 grammes.

On board the gunnery training ship *Louis XIV*, as also at the camp at Châlons, experiments were made which fully demonstrated the advantages of the system, and the Minister of Marine lent to the Society some bronze swivel-guns 80 kilogrammes in weight, and some blunderbusses of 20 kilogrammes.

The first, discharge a wrought iron arrow, weighing 5 kilogrammes, a distance of 300 metres, with a charge of 140 grammes of powder, and bearing a line $5^{mm},5$ in diameter; or 150 metres, with 50 grammes of powder and a floating arrow of wood weighing 2 kilogrammes. This last is carried the same distance by the blunderbuss, with the same charge.

Some time afterwards the Ministry of Marine added the loan of some wall-pieces. These guns discharge a wooden arrow weighing 280 grammes, discharge a line $2^{mm},5$ in diameter, a distance of 100 metres, with a charge of 5 grammes of powder.

All these ranges, just mentioned, may be taken as the average results of a number of experiments, made under the conditions of calm weather or light cross breezes. The proportion is considerably augmented or diminished, according to the strength and direction of the wind.

But guns for military purposes are deficient in the conditions most favourable to the discharge of these arrows, and for the following reasons M. Delvigne proposed to have guns made expressly for the purpose:

1. Considering that, in order to avoid breaking the lines, the arrows can only be discharged with a velocity much inferior to that given to projectiles of war, it follows that long bore pieces are useless;

2. In default of velocity, a sufficient range can only be obtained by the weight of the arrow, from which follows the necessity of a relatively strong charge, and a great power of resistance in the gun;

3. The arrow can be considerably lengthened, and by this means great weight is obtained with a small calibre, and the length of bore being reduced, the thickness of the metal can be increased without exceeding the weight of the war gun.

In accordance with these considerations, the small steel gun with carriage was established, serving, with the blunderbuss of the same weight, as a mean of comparison in respect of the range to be obtained.

The gun-cannon (fusil-canon), invented by M. Delvigne, can be fired from the shoulder, with a charge of 10 grammes; with a double charge by means of a support for the hook or rest at the extremity of the piece, and with a triple or quadruple charge, when the piece is placed on its little wooden carriage.

The trials demonstrated that, with a simple charge, it will carry a wooden arrow 400 grammes in weight, with a line $2^{\mathrm{mm}},5$ in diameter, a distance of 130 metres.

When the line, fired by one of these pieces, reaches the people in the vessel, they make use of it to haul on board a double gantline, which is rove in a single block attached to the mast. By means of this, the people on shore send a hawser, which the crew make fast above the gantline, and then a round buoy with a leather sack, in which the shipwrecked people are successively brought to land. Such is the reciprocal movement of the apparatus.

Other methods are employed, which, though they do not carry aid to so great a distance, are valuable on certain occasions:

Life-belts. — Various systems have been tried by the Society, and the preference has been given to the one invented by rear-admiral Ward. This consists of broad pieces of cork sewed on a linen band; it is simple and solid, offers no obstruction to the movement of the body, and can be delivered at the price of 6 fr. 50 cent. This belt is very generally used along the coast; all the life-boats, and the craft attached to the lighthouse service, and a great number of fishing boats are provided with it.

The Torrès lines. — All vessels ought to be provided with this apparatus, the utility of which is daily experienced in our ports. The invention is due to M. Torrès, of Havre, and consists of a line 6 or 8 metres in length, with a small cork buoy at one end, and a number of small pieces of wood along its length. If a man falls from the quay, by no means an uncommon occurrence, the line is immediately thrown to him, and he holds on to the buoy or one of the pieces of wood. He can even roll it round his body, and thus make a complete life-belt.

Leaded staves. — These are used to throw a line on board a small craft in distress at the entrance of the port.

Stations established. — Up to the present date the Society has established 50 life-boat stations, and 325 stations of rescue. The latter are confided to the care of the revenue officers, and are furnished with mortar apparatus, belts, and other appliances of rescue. Thirty-one sea light-houses have been provided, by the Society, with wall-pieces (fusil de rempart) and wooden arrows.

The Society publishes, under the title of *Annales du Sauvetage Maritime,* a journal containing an account of its transactions, as well as of all inventions and occurrences relating to the object of its mission.

Results obtained. — From the period of its formation to the 1st January 1876, the Society has rescued 1,247 shipwrecked persons from death. Assistance has been afforded to 270 vessels in distress, and 75 of them have been saved.

For these rescues, it has awarded numerous gratuities and the following honorary distinctions:

10 gold medals,
64 silver medals,
179 bronze medals,
295 certificates.

On the recommendation of the committee of management, seven cockswains of life-boats have received the decoration of the Legion of honour.

On the 5th May 1872, the Society suffered a grievous loss in the death of the president, admiral Rigault de Genouilly. The council of administration nominated, as his successor, vice-admiral baron de La Roncière-le-Noury, who had previously fulfilled the duties of president of the committee of management.

The president of the committee is M. DUMOUSTIER DE FRÉDILLY, director of Commerce at the Ministry of Agriculture and Commerce. M. Camille DORÉ, retired naval officer, is the acting delegate.

M. ROUBET, retired naval captain, and M. RAGIOT, naval lieutenant, are the Society's inspectors.

The seat of the Society is established in Paris, rue du Bac, 53.

SECOND PART.

MINES.

LIX

DETAILED GEOLOGICAL MAP OF FRANCE

EXECUTED ON THE TOPOGRAPHICAL MAP OF THE STAFF

BY THE GEOLOGICAL MAP SERVICE.

The geological map service of France was instituted by a decree of the 1st October 1868, with a view to the publication of a detailed geological representation of the country, upon the Staff map on the 80 000th.

For nearly two thirds of the territory, the elements of this publication were already in existence, in the shape of departmental maps executed under the auspices of the general councils, at different periods since the year 1835. But these maps, executed and published on different scales and without any common plan, could neither be brought together for purposes of comparison, nor with the object of constituting one complete work. In addition to this, few of them showed any acquaintance with the recent progress of a science which during the last few years has received the most valuable accessions.

In 1868, the *personnel* of the service was placed under the superintendence of M. Élie de Beaumont(1), whose first efforts were directed to the study of the Parisian district, and it was soon ascertained that, whatever care might have been exercised in the previous surveys of this district, it was necessary to recommence, in almost every part, the detailed exploration of the ground.

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(1) This *personnel* consisted of MM. Élie de Beaumont, senator, perpetual secretary of the Academy of Sciences, inspector general of Mines, director of the service; B. de Chancourtois, engineer in chief of Mines, sub-director; Edmond Fuchs, A. Potier, A. de Lapparent, H. Douvillé, F. Clérault, mining engineers; Guyerdet, attached to the collections; Jedlinski, principal garde-mines, charged with the graphic works.

For the documents composing a work of this magnitude, it was necessary to establish a methodical and uniform system of arrangement, capable of adequately meeting all the scientific and technical requirements that geology is called upon to satisfy; and this obligation, added to the necessity, before mentioned, of a new and more complete exploration, prevented the publication from being accomplished with the promptitude calculated upon at the commencement of the undertaking. In 1873, the work was not sufficiently advanced, to allow of sending to the Universal Exhibition at Vienna more than twelve sheets, forming a rectangle, of which Paris occupies nearly the centre, with their annexes, explanatory notices, longitudinal and vertical sections, photographic perspectives, etc. It should also be borne in mind, that at this period there were many obstacles to be encountered. The limited number of the members of the service, all of whom had other special functions to perform, in addition to their geological duties; financial necessities, defective organization of the service; all these circumstances concurred in retarding the progress of the work.

In 1874, a new arrangement of the service was necessitated by the death of the learned and illustrious man at the head of the work. The direction was confided to M. Jacquot, inspector general of Mines, and in the course of 1875, on the proposition of M. Caillaux, Minister of Public Works, the National Assembly, justly impressed with the importance of the undertaking, did not hesitate to renew a grant, by the aid of which the publication of from twelve to sixteen sheets per year may be expected, consequent upon the employment of an additional number of assistants, so that the completion of the work may be looked forward to, in a period of from sixteen to twenty years.

The actual staff of the geological map service is composed of

MM. Jacquot, inspector of Mines, director.
Moissenet, mining engineer, director of the assay department in the School of Mines.
Edmond Fuchs, A. Potier, A. de Lapparent, H. Douvillé, engineers.
Guyerdet, attached to the collections.
Jedlinski, principal garde-mines, charged with the graphic work.

Besides indicating the authorities consulted, each sheet mentions the name of the engineer or engineers entrusted with the survey.

The publication has, hitherto, been carried on at the National Printing Office.

DOCUMENTS EXHIBITED.

These comprise :

1. A central panel formed by the union of twelve sheets representing the extreme north of France.

Although the advantage of the grant voted by the Assembly in 1875 can only be realized in the course of 1876, the geologic map service is now able to exhibit a new series of twelve sheets, all published or in the press, viz.:

N° 3 (Boulogne), 4 (Saint-Omer), 5 (Lille), 6 (Montreuil), 7 (Arras), 8 (Douai), 11 (Abbeville), 12 (Amiens), 13 (Cambrai), 20 (Neufchâtel), 21 (Montdidier), 22 (Laon).

The panel, composed of twelve sheets united, shows the northern limit of the Parisian basin, in contact with the upheaval known as the axis of the Artois. It includes also the Bas-Boulonnais, where numerous strata crop out, and the greater part of the district of Bray, of which the irregular upheaval is observed in bold relief, in the middle of the plateaux with a substratum of chalk, in Normandy and Picardy. The influence of this upheaval is obviously manifest in the rectilinear direction of all the valleys in Picardy, as well as by the lower chalk cropping up at the surface, in those valleys following the axis of the parallel anticlinal bends.

The underground survey of the coal basin of the Nord and of the Pas-de-Calais has been made with scrupulous care. After drawing up a detailed abstract of all the borings for coal, a special plan indicates on the map the curves of level which show the appearance of the ancient surface, at its contact with the cretaceous deposit known under the name of *tourtia*. On the Arras sheet these curves are conspicuously important.

They enable an intimate relation to be established between certain accidents of depth and external features which characterise the convexity of the Artois and the faults by which it is accompanied.

The numerous faults in the Bas-Boulonnais have been depicted with all possible accuracy, as well as those which on the Neufchâtel sheet, bound at the north-east the upheaval of the district of Bray. Also, on the sheets of Douai and Cambrai, care has been taken to omit none of the croppings of eocene sand and plastic clay, which occupy, for the most part, singular positions in the fissures of the chalk, owing to a convulsion or falling in, after their deposit.

Mining operations are indicated on all the sheets, by a sign characterising the substance worked.

2. Two side panels with different specimens of sheets.

The left side panel contains, besides the title sheet and introduction, a longitudinal section carried across the Beauvais sheet, in a transverse direction to the axis of the district of Bray. Below, is a copy of the Arras sheet, with the curves of the level of the ancient surface.

The right side panel comprises a trial sheet on the 40 000th, relating to the outskirts of Paris, two sheets of vertical sections, one for Paris, the other for the environs of Beauvais, and two photographs of quarries, reproduced by the photoglyptic method, and in which the perspective has been arranged in accordance with the corresponding geological scale, by a geometrical diagram.

3. A longitudinal section on the $\frac{1}{80000}$ and $\frac{1}{10000}$ carried from north to south, across the Paris sheet, is figured below the three panels.

4. A special panel, comprising the Calais sheet, shows the results of the survey undertaken by two of the engi-

neers of the geological service, MM. Potier and de Lapparent, with a view to the construction of the submarine tunnel between France and England. The croppings up of the strata of gault, glauconite chalk, and marly chalk, under the straits between Calais and Dover, are represented as shown by the boring operations. The existence of two dips has been remarked in the bearing of these croppings; one on the French, and the other on the English side, between which no geological irregularity of importance is anticipated.

This submarine geological survey has been traced according to the plan attached to the report of the French submarino railway association, and is exhibited with their permission.

5. Map on the $\frac{1}{40000}$ of the *south-western district of the Morvan*. Environs of *Saint-Honoré-les-Bains*.

The environs of Saint-Honoré are principally composed of porphyritic rocks bordered on the east by a granitic mass north-east-south-west, and disappearing in the west, following a general north and south direction, under a covering of jurassic and tertiary deposits.

Among the varied porphyritic rocks of this district, the most ancient appear to be volcanic, and are accompanied with tufa, diamorphic and metamorphic rocks. Their freest type agrees with the black anthraciferous porphyries, the epoch of which can be assigned with precision in the outskirts of Autun, where they are covered by the upper coal stratum. Towards Champrobert and the east of Villapourçon, they are superposed by outliers of carboniferous limestone.

In the middle of this formation of intermediary porphyritic rocks, appear vast masses of acid quartziferous porphyry, extending through all Morvan, and of which the age can be determined with equal facility, since on the one hand, they traverse the lower coal measures, and on the other, pebbles are found in the conglomerate of the upper coal stratum of Autun. Nevertheless, some of these porphyries appear to traverse the first strata.

The following formations are indicated in the map exhibited :

	SEDIMENTARY STRATA.	ERUPTIVE ROCKS.
	Alluvial	
	Tertiary strata.	
	Inferior oolite.	
Lias	....	Quartzose veins.
Upper coal formation	....	Granitic pinite.
Lower coal formation	....	Talcous eurite or granite.
	....	Quartziferous porphyries with large crystals.
	Porphyritic sandstone.	
	....	Black porphyries.
	....	Porphyritic tufas.
	Quartzites.	
Carboniferous stratum	Carboniferous limestone.	
Devonian stratum	....	Granulites.
Silurian stratum	....	Granite with large crystals.

The *carboniferous limestone* formation is represented by the marbles (Champrobert) and calciferous schists (east of Villapourçon). The limits of these croppings are marked by large fractures.

The *lower coal* formation may be divided into four stages:

1. The base is composed of metamorphic *quartzites*, frequently pyritous, which commence by conglomerates with quartzose pebbles, and terminate in breaches already porphyritic.

2. These breaches pass to the *porphyritic tufas*, containing in great abundance fragments of crystals much broken, and of very different dimensions. The older quartz and mica are found associated with hornblende, often transformed into serpentine, and with numerous fragments of felspar, especially triclinic. The magma is amorphous, fluidal in mass, and here and there presents some veins of concreted chalcedony.

3. The black porphyries are rocks analogous to the preceding, but more compact, less acid, and often fluid by microlites.

4. Finally, the rosy *porphyritic sandstone* constitutes, in the environs of Saint-Honoré, the most elevated term of the series, and appears analogous to that contained in the layers of anthracite in the Loire.

The veins of *quartziferous porphyry* which cut the preceding series may be divided into three categories:

1. *Porphyries of the lower coal measures, with large crystals,* brown, red, mottled, or even entirely black, with blackish pinite and chlorite or magnesian mica, sometimes with a substance aphanitic, sometimes with a magma entirely crystallized, and visible to the naked eye.

Submitted to the microscope, these porphyries present all the combinations between the micro-granulites (Luzy) and the micro-pegmatites (summit of mount Genièvre), and frequently constitute beautiful micro-pegmatites with starrings (les Forges near Chides).

2. *Porphyries of the lower coal formation, mostly granitic,* of a pink or greenish element, rich in talc, and containing a greenish pinitoid substance, but destitute of real pinite in hexagonal prisms. These rocks also pass from varieties entirely crystallised, to absolutely compact silicious stone. By the aid of a magnifying glass, small globules may be distinguished, which give them an oolitic appearance. In the microscope they present beautiful varieties of micro-pyromerides with globules clustered together in a granulitic magma rich in talc.

3. *Euritic or granitic porphyries of the upper coal formation,* with a grey or pink element, containing real pinite and resembling the elastic eurite of the Selle near Autun. In the microscope, these rocks are delicately spheroidal. The greater part of their globules are extinguished under the crossed nicols, but some of them present indications of black cross.

The porphyries of the lower coal formation fill extensive sheaves of fractures, tending N. 29° E. and N. 38° 30′ E.; those of the upper coal formation appear almost always in a direction nearly east and west, are besides not very abundant.

To the eruptive rock-dykes in the district, succeed veins concreted with quartz, barytine, fluorine, hematite, pyrites, and galena. This is the ordinary filling of the veins of the *liasic arkoses.*

The mineral waters of Saint-Honoré-les-Bains were used by the Romans, and appear to have their source in one of these veins, at its point of meeting with the wall of a porphyritic dyke.

6 and 7. *Enlarged photographs of eruptive rocks cut in thin plates.*

Each of the groups of photographs exhibited comprises six different rocks, reproduced with an enlargement of from 30 to 50 diameters. The apparatus, constructed by M. Nachet, permits the employment of polarized light.

Tableau n° 6 reproduces the granites, granulites, and pegmatites collected in France and in the Colorado. It indicates the analogy existing between the two granitic and granulitic series in Europe and America, and gives examples of the frequent mixtures of orthose, microtine and albite, presenting themselves under the form of recent felspar, and filtering through the quartz the debris of the old felspar, lumped together.

Tableau n° 7 comprises porphyritic types principally collected in the Morvan. It shows the fluidal structure of the black anthraciferous porphyries, the micro-granulites, the micro-pegmatites and the micro-pyromerides with globules in extinction, previous to the upper coal formation, and finally the fluidal structure and the petrosilicious veins peculiar to the permian quartziferous porphyries.

The surveys relating to the plans and designs exhibited under n^os^ 5, 6 and 7, were made by M. Michel Lévy, mining engineer, who also assisted at the preparation of the geological map.

LX

GEOMETRY OF THE «PENTAGONAL RÉSEAU»

AND GRAPHIC SPHERODESY.

Instruments (case).
Spherical drawings (models).
Plane drawings (panel and portfolio).
Notices (thin books).

The geometry of the pentagonal réseau being susceptible of application irrespectively of geology, a separate collection has been made of the models, maps and papers intended to popularize the knowledge of it, as also the method of drawing on a sphere. Although these subjects are combined for the study of the réseau and of the geological alignments, they have themselves a more general range.

A. *Directions for the practice of geometrical drawing on the sphere, and for its application to geography and geology.* (Extract from the Annales des Mines, 1875.)

B. *Sphere in stucco* representing the terrestrial globe diminished to the 100 000 000th (the one hundred millionth). Radius = $0^m,0637$, circumference = $0^m,4$, a degree = $0^m,0011$, a grade = $0^m,001$.

C. *Spherodesic instruments* adapted to the *preceding sphere.* Rule (great circle), square (bi-right-angled-triangle); compasses (beam compasses).

D. *Spherical drawing of the geodesic duodecimal,* showing the meridians and parallels at every 10 degrees.

E. *Spherical drawing of the geodesic decimal,* showing the meridians and parallels at every 10 grades.

F. *Spherical drawing of the pentagonal réseau,* comprising the plan of the 121 principal circles; regularly coloured.

G. *Plane drawing* entitled the PENTAGONAL *Réseau summing up the relations of the five regular solids established in geology as the principle of co-ordination of the systems of mountains and of other facts of alignment, by M. Élie de Beaumont.* 1850.

This drawing, which was executed in 1874, presents, with an explanation in detail, the orthogonal projection of the réseau on the plane of one of the primitive circles and its gnomonic projection, for the quarter of the sphere, on the tangential plane which is the horizon of the centre of a pentagon. It corresponds to the spherical drawing, (F), and the figures are composed of the same 121 principal circles, and coloured in the same manner.

H. *Applications of the preceding plane drawing.* Examples of geometrical itineraries of circles of which the poles are given.

K. *Notice* entitled : *On the pentagonal réseau of M. Élie de Beaumont.* (Extracted from the report of the Geological Society, 1875.)

L. Besides the directions (C) and the notice (K), the models, maps and papers exhibited under the number LX are accompanied by an *explanatory notice* by the principal author M. A.-E. Beguyer de Chancourtois, engineer in chief of Mines and professor of geology at the National School of Mines, who there mentions the names of the different contributors.

LXI

STUDY OF THE GEOLOGICAL ALIGNMENTS

AND

APPLICATION OF THE "PENTAGONAL RÉSEAU."

Chart of survey on the 80000th (panel).
Globe with special mounting (model).
Gnomonic planisphere (panel and portfolio).
Numerical tables, dissertations, notices (thin books).

The study of the geological alignments, caused by the stratigraphic surfaces of the terrestrial crust, adjacent to the vertical, is continued from the facts of the last detail which directly concern the working of mineral deposits, unto the facts of the ensemble relating to the distribution of these deposits and of the eruptive phenomena. In all the degrees, these facts are shown in relation to orographic and hydrographic data. As a starting point, the result of a local study touching on the practical, is first presented. Then come an apparatus arranged to facilitate the most general theoretic study on the entire surface of the globe, and the application of the pentagonal réseau of M. Élie de Beaumont, — a gnomonic planisphere constructed for the same purpose, — also, the first results of the employment of these means of investigation and demonstration.

STUDY REFERRING TO A DISTRICT.

A. *Distribution of the mineral gites subordinate to the sedimentary deposits, by groups of alignments parallel to the other* *geological alignments and to the bearings of the mountain systems in the region of the Upper Marne,* represented on the geological chart of this department on a scale of the 80 000th, with a compass of bearings observed.

B. *Stratigraphic studies,* joined to the preceding chart. Papers in which M. Élie de Beaumont has treated the observations upon the relations existing between the bearings ascertained, and those of the circles of comparison of his systems of mountains, and M. B. de Chancourtois, after describing the facts of the alignments which he has observed, and which form the subject of the preceding remarks, extends this study to the third north-east of France, by the aid of the geological chart on the scale of the 500 000th.

STUDY CARRIED THROUGH THE SURFACE OF THE GLOBE.

C. *Tables of the numerical data fixing the circles and points of the pentagonal réseau,* published by M. Élie de Beaumont in the Transactions of the Academy of Sciences, 1863 and 1866.

D. *Application of the pentagonal réseau to the co-ordination of petroleum springs and bituminous deposits, extended to the co-ordination of the points or lines of eruption and emanation and of mineral gîtes in general.* Paper of M. B. de Chancourtois. (Extracts from the Transactions of the Academy of Sciences, 1863.)

One of the conclusions of this paper is that the alignments are grouped on the globe, in systems of *great circles connected,* each system being determined by one *great normal circle.*

E. *Globe on the scale of the 50 000 000th.* With the spherodesic instruments (see LX) and by means of the numerical data of the tables (C), as a preliminary, *the 31 first principal circles of the pentagonal réseau* are traced upon this globe. Then, with the same instruments, and the armillaire before mentioned (F), are traced some of the alignments described in the paper (D).

Among others is traced notably *the system of great circles which has for its normal the primitive of the Rhine.* There are in this system some terms particularly worthy of remark, viz., the circle of comparison of the Pyrenees which passes by Etna, where its bearing is observed in the principal ridges of the Val del Bove, and the groups of lines of fracture which may be followed from the gîtes of petroleum of Bakou, at the extremity of the Caucasus, to the gîtes of the region of Ohio, and from the mouth of the Volga to the mouths of the Mississipi.

F. *Armillaire à coupoles,* fitted for the study of the facts of alignments on the geographical globes, and especially for the verification or enquiry into the systems of alignment subordinated to one normal.

It allows the globe to be turned round the axis of the poles of a given normal, and this axis to be brought into the plane of the horizontal limb, at the level of which the rotation of the globe presents successively all the alignments of the system actually studied.

G. *Octo-planisphere gnomonic. Map of the globe delineated in gnomonic projection on the eight faces of a regular circumscribed octahedron* of which the eight triangles juxtaposed show the development with indication of the principal points of the pentagonal réseau which mark on the rectilinear tracing of this réseau, constructed for the *study of the geographic alignments* in general by M. *B. de Chancourtois.*

The globe to which this map corresponds is the reduction of the terrestrial globe to the 100 000 000th. One of the axes of the octahedron is put in coincidence with the axis of the poles, and two of the edges correspond to the meridian of the Ile-de-Fer.

By the principle of gnomonic projection, the great circles of alignments are represented by straight lines, but these, in their development, assume the form of a polygon. An accessory map furnishes the means of constructing the polygon, determined by one of its sides, or by two points belonging to two different faces.

H. *Notice on the map of the globe in gnomonic projection*, pointing out its advantages not merely to geology, but to hydrology and meteorology. (Transactions of the Academy of Sciences, 1873.)

K. *Studies of systems of alignments on the gnomonic octoplanisphere*, affording, with or without the tracing of the pentagonal réseau, the principal systems of alignments described in the paper of M. B. de Chancourtois, before mentioned (D).

L. An *explanatory notice* more detailed than the present accompanies the models, maps and drawings exhibited under number LXI, and terminates by showing their correlation. It indicates the part taken in the preparation of this exhibition by M. Beguyer de Chancourtois, engineer in chief of Mines and professor of geology at the National School of Mines, and also mentions the names of his fellow contributors.

LXII

MAP OF THE BEDS OF PHOSPHATE OF LIME

KNOWN OR ACTUALLY WORKED IN FRANCE.

Since the year 1855, the extraction of phosphate of lime has attained a great development. The explorations undertaken by M. de Molon, according to the geological indications furnished by M. Élie de Beaumont, showed that phosphate of lime, in concreted nodules, existed along all the outcrop of greensand in the north and north-east of France, the Pas-de-Calais, the Ardennes, the Meuse, etc. Its existence was also established under analogous conditions of deposit, in the Perte-du-Rhône (Ain) and in the Drôme. More recently M. Poumarède discovered the beds of phosphorite at Quercy (Lot and Tarn-et-Garonne), while nodules were observed at various levels in the chalk formation. At length M. de Molon discovered phosphorite at the base of the lower oolithe, in the department of Calvados, but up to this time no attempt has been made to work this deposit.

The agricultural importance of this mineral is such that it has been deemed necessary to delineate, on a special map, the various deposits known or worked in French territory.

In the following classification different colours are used to distinguish the various deposits:

1. *The tertiary deposits,* viz. those of Tarn-et-Garonne, the Lot (or Quercy) and the Aveyron, where the concreted

phosphorite fills the hollows and fissures of the jurassic limestone. The advent of the mineral matter appears to have coincided with the appearance of iron in a granulated form and the deposit of Parisian gypsum.

The phosphorite of this region, called Quercy, contains as much as 70 p. o/o of phosphate of lime. A large quantity is sent to England, where, by the aid of sulphuric acid, it is changed into superphosphate. This process is also carried on in France, at the works of Chauny, through the agency of the Society of Saint-Gobain.

In the Lot, the Tarn-et-Garonne and the Aveyron, this mineral is worked in more than 35 communes. But the deposits are so thin that no great length of time can elapse before their exhaustion.

2. *The deposits in the upper chalk,* viz. those observed by M. Meugy in the *tun* de la Flandre, at the base of the white chalk and at various depths in the chalk of the Ardennes; also those remarked by M. Guillier in the chalk of the Sarthe, and those in the Ardennes at the base of the chalky marls, in which the phosphate is often found in the form of coprolithes.

3. *The deposits in the greensand.* These are the most abundant and most regular, and form beds of concreted nodules and fossils transformed into phosphate of lime and of iron; they are found in the green chalk, in the clay and the greensand. Till lately, the greensand deposits were only worked on the eastern border of the Parisian basin, but they have been recently discovered on the southern side, and are worked at Vailly near Sancerre, in the department of the Cher.

The deposits capable of being profitably worked are indicated on the map by a dark tint, while those in which the nodules are disseminated in small quantities, are distinguished by a light tint.

In 1873, the quantity extracted in the department of the Meuse attained to 41,000 tons, and about 23,000 tons in the Ardennes. It is estimated that the department of the Meuse can supply 80 millions of tons of nodules, two thirds of which can be extracted in open air or by little shafts. The other third will require regular underground working.

The average quantity of phosphate of lime contained by the nodules varies from 40 to 50 p. o/o, and the price is from 29 to 31 francs per ton.

In the Pas-de-Calais, the average is comprised between 37 and 50 p. o/o, and the price per ton, pulverized, is from 40 to 50 francs.

The nodules of the Perte-du-Rhône contain 50 p. o/o of phosphate, and those of Clansayes, in the Drôme, 35 p. o/o.

The phosphate nodules everywhere accompany the outcrop of greensand, but in Normandie, as also in the Orne, the Nièvre, the Yonne, the Aube and the Marne, the beds are not sufficiently large to be worked profitably.

4. *A special tint has been adopted for the beds of phosphorite* which do not enter into any of the preceding categories, as in the case of those disseminated in the jurassic formations or the older rocks (apatite de Chanteloube). Microscopic examination has lately shown that a great number of the

primitive rocks contain apatite in close alliance, but this substance has not yet been found in paying quantities.

The map has been drawn by the aid of documents furnished by the museum of mineral statistics of the School of Mines, completed by the observations of M. d'Ambly, engineer in chief, and MM. Lachat, Chosson and Nivoit, resident engineers.

The work was executed under the direction of M. Daubrée, inspector general, member of the Institute, director of the National School of Mines, by M. de Lapparent, resident engineer, assistant conservator of the collections of departmental statistics, with the aid of M. Lejard, draughtsman.

LXIII

HYDROLOGIC MAP

OF THE DEPARTMENT OF THE SEINE AND MARNE.

Map on a scale of $\frac{1}{100000}$ (one hundred thousandth).

The hydrologic map of the department of the Seine-et-Marne shows the subterranean sheets of water in the region of the Brie, figured in conventional colours. Their form has also been determined, in accordance with a geological survey of the subjacent strata, as well as the levels taken in a system of wells or shafts. Their upper surface is represented by the numbers above the level of the sea, which have been obtained for each shaft, and by horizontal curves 20 metres apart, so that it is easy to understand their mode of flowing.

In the region of the Brie, the principal underground waters capable of being clearly defined correspond to the most important clay strata, i. e. to the green and plastic clays, and in some hills, to the millstone clays of the Beauce.

In addition to this, the subterranean sheets attributed to filtration correspond to the various water courses which traverse the Brie, and especially to rivers like the Seine and Marne.

That borne by the green clays is by far the most important, since it supplies the wells of the plateau of the

Brie, while in the valleys the wells are supplied by the filtration of the subterranean sheets.

The hydrologic map of the department of the Seine-et-Marne indicates the relief of the surface by means of horizontal curves, determines the depth at which the subterranean sheets of water can be reached, and shows the relations existing between the sheets of water and the geological formation of the ground. It shows, in particular, the action of the waters in a permeable soil, such as chalk, a consideration entitled to some attention at the present time, when the project of a tunnel, between France and England, is being contemplated.

This map was drawn by M. Delesse, engineer in chief, professor at the School of Mines.

LXIV

AGRICULTURAL MAP OF FRANCE.

A map on a scale of $\frac{1}{4000000}$ (one four millionth).

On this map the different cultures are shown by conventional colours, of which the shades are deeper as the revenue is more considerable.

The products of the arable lands which occupy the greatest part of France vary every year, but it is still possible to estimate in money the average annual revenue per hectare. By studying the amounts given for the cantons, and keeping well in mind the form of the latter, as well as the altitude and mineralogical composition of the soil, curves have been traced corresponding to annual revenues of 20, 40, 60, 80, 100 and 120 francs.

For the woods, meadows, and vines, of which the cultivation is permanent, curves indicating equal revenue have been traced, according to the average per hectare.

Their conventional colours being assigned to the woods, meadows, and vines, the shades have been graduated according to their revenues, and they are limited by the various curves which correspond to them.

The map exhibited is a reduction of the work to the very small scale of 4,000,000; it however furnishes a means of appreciating the distribution of the agricultural riches of France.

This map was drawn by M. Delesse, engineer in chief, professor at the School of Mines.

LXV

GEOLOGICAL PROFILE FROM PARIS TO BREST.

Scale of $\frac{1}{40000}$ (one forty thousandth) for the lengths.
Scale of $\frac{1}{2000}$ (one two thousandth) for the heights.

The profile follows the track of the railway which, starting from Paris, passes through Bonneval, Châteaudun, Vendôme, Tours, Angers, Nantes, Vannes and Quimper, and terminates at Brest. Several classic regions are traversed in this journey, which embraces the Parisian basin, the Beauce, Touraine, the valley of the Loire and a part of Bretagne.

On this profile may be followed in succession the different geological formations which have been marked all along the line of railway. Their position is specified by their elevation above the level of the sea, so that notwithstanding the exaggeration of the scale of heights, it is easy to understand their relative bearings.

In the region of the Beauce, the subterranean sheets of water have been specially studied.

The profile also furnishes particulars respecting the materials of construction supplied by each geological formation, as well as upon the vegetable soil and the nature of the cultivation.

Geological studies of this character would be eminently useful, if undertaken before the execution of a line of railway, since they would give a just idea of the difficulties to be encountered in its construction, and would point out the resources to be calculated upon in the districts traversed. But even when made after the completion of the line, they still afford data valuable to science and to industry.

By order of M. de Franqueville, director general « des Ponts et Chaussées » and of Railways, these geological studies have been pursued by M. Mille, inspector general, in a great part of France.

The geological profile from Paris to Brest has been executed under the direction of M. Mille, engineer in chief « des Ponts et Chaussées », by MM. Triger, civil engineer, Delesse, engineer in chief of Mines, Thoré, resident engineer « des Ponts et Chaussées », and Guillier, conductor « des Ponts et Chaussées ».

LXVI

LITHOLOGIC CHART

OF THE SEAS OF EUROPE.

A chart.

This chart is drawn according to the hydrographic works, and shows the nature of the rocks found at the bottom of the European seas.

The basins of these seas are indicated, in the first place, by horizontal curves, traced according to the depths given by numerous soundings. The rocks distinguished are the various stony rocks, clay, mud, sandy mud, muddy sand, sand, gravel and shingle. They are represented by conventional colours, as in works on geology, but one colour indicates only one lithological character. Deposits rich in shells have also been marked out and are indicated by hatchings.

Amongst the rocks forming the bottom of the seas, some are anterior to the present epoch and are wearing away by corrosion, so that they are not covered by deposits. They may be stony, as granite, sandstone and limestone, but they are often soft, as clay, or even completely movable, as sand and shingle. These rocks anterior to the present epoch are specially noticed where prominences occur, as in straits, and generally in those localities where the action of currents is particulary strong. The rocks belonging to deposits of the present epoch are essentially movable, and fill those parts which present hollows or depressions. They also cover the plateaux, and accumulate more especially in bottoms over which the water passes slowly.

The geologic study of the coasts, compared with the results of soundings, sometimes assists in tracing under the sea the continuation of the rocks which are out of the water; it also allows some outlines of a *sub-marine geological* map to be sketched.

This chart is the work of M. Delesse, engineer in chief, and professor at the School of Mines.

LXVII

VENTILATION OF THE GLAZED COURT

OF THE LABORATORIES OF THE SCHOOL OF MINES.

Three drawings [1].

1. Plan. — 2. Section of the breadth. — 3. Section of the length.

These drawings show the whole of the glazed rooms and the sand-baths, the fireplaces of which warm the great metal chimney and create the draught. This chimney receives all the noxious gases from the glazed rooms, as well as the vapours from the sand-baths.

The great chimney in copper is supported by a stone pillar, to which are attached the granite washing stones.

The upper part of this chimney is surrounded by a glazed covering or sky-light, with a round orifice to let out the air more or less impure.

Four air-shafts lead from the cellars to the surface and on each side of this court.

This project is due to M. Wallez, architect of the School of Mines.

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(1) These three drawings are accompanied by a frame containing four engravings, representing:

The plan of the whole of the buildings of the School of Mines;

The plan of the ground-floor of the laboratories;

The plan of a pupil's laboratory, and plans and sections of a sand-bath in a pupils' laboratory.

LXVIII

NATIONAL SCHOOL OF MINES.

INSTITUTION AND OBJECT OF THE SCHOOL.

This School was first instituted in 1778, and subsequently re-established in 1816. The control is vested in the department of Public Works, and its principal object is to furnish the training and instruction necessary for the engineers required by the Government for the mining service.

Independently of the *engineer* pupils, the School receives élèves externes, foreign pupils (*étrangers*), and pupils unattached (*libres*).

The *engineer* pupils, who are taken exclusively from pupils leaving the Polytechnic School, are alone eligible for the Government service, and are nominated by decree.

The élèves *externes* are prepared for the various positions offered by commerce and manufactures, and in particular, to enable them to become engineers or directors of mines or mineral works.

They are admitted by competition, conformably to the annexed double programme (1).

The *foreign* pupils are admitted by a decision of the Minister, on the request of the ambassadors or chargés d'affaires of foreign powers.

The pupils unattached (*libres*) are, at their own request, simply authorised by the Minister to follow the studies and lectures of the School.

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(1) See documents presented to the Universal Exhibition at Philadelphia.

The course of study is the same for the various pupils, but the foreign and unattached pupils can only participate in the practical exercises, in proportion to the number of places disposable, in the laboratory and in the drawing school.

At the close of each scholastic year, the engineer pupils and élèves externes pass examinations on the courses followed. The foreign pupils have the option of presenting themselves, but the unattached pupils are not admitted to these examinations.

On leaving the School the engineer pupils are appointed resident engineers of the 3rd class, and the élèves externes whose acquirements are satisfactory receive a certificate of merit and are authorized to bear the distinction of *certificated* (*brevetés*) *pupils of the National School of Mines in Paris.*

The foreign pupils receive simply the certificate of merit.

PREPARATORY COURSE.

To facilitate admission to the rank of élèves externes, preparatory courses were instituted at the School of Mines, by a ministerial decision of 26th December 1844. These courses are followed by two classes of pupils:

The *titular pupils of the preparatory courses* are admitted by the Minister after a competitive examination, and the unattached pupils, either French, or foreign, who are simply authorized by the Minister, on making personal application.

The pupils of the first of these divisions, only, are required to pass an examination at the close of the scholastic year.

Candidates for the position of titular pupil in the preparatory course must fulfil the conditions required in the annexed programme. (Preparatory courses.)

The preparatory studies consist of four oral courses of lectures and practical exercises.

The courses comprise :

1° Ideas of infinitesimal analysis and mechanics;

2° Descriptive geometry, pure and applied;

3° Physical sciences, in relation to gas and vapours, heat and optical instruments;

4° Chemistry in general.

Two of these courses consist of 25 to 30 lectures, and the other two, of 55 to 60 lectures given from the 7th November to the end of May.

The programme of the courses is the same as that of the studies required for admission to the places of élèves externes, with the exception of geography and cosmography.

The practical exercises consist in geometrical drawing and shading.

COURSE OF THE SCHOOL OF MINES.

The principal objects of the instruction given at the School are the opening and working of mines and the treatment of mineral substances.

It embraces three years of study, and comprises, in addition to the lectures, practical exercises and travelling studies.

The pupils of the *first year* attend the seven courses of working and machinery, metallurgy, mineralogy, assaying, geology, paleontology, and drawing plans.

The pupils of the *second year*, the second part of the four courses of working and machinery, metallurgy, assaying, and geology.

The pupils of the *third year*, the four courses of industrial constructions and railways, mining legislation. administrative law and industrial economy, agriculture, drainage, irrigation and military fortification.

The oral teaching comprises in addition German and English, and the pupils are compelled to attend the course of one of these foreign languages.

The oral courses open each year, from the 7th to the 15th November, and close on the 15th April.

The practical exercises are thus divided:

During the term of study, the pupils of the first and second year work alternately in the laboratory and at drawing; they also study the collection of the School of Mines and visit the manufactories and works in the neighbourhood of Paris.

After the May examinations, the pupils of the first year are exercised in chemical analyses till the 15th July, and in plan-drawing till the 15th August. The vacation commences at that date, but they are expected to visit, for three weeks in September or October, one of the principal mining and smelting districts in France or Belgium.

During the first fortnight in June, the pupils of the second year attend a course of geology under the direction of their professors, and afterwards in the summer they visit various mining and manufacturing districts, in accordance with a programme drawn up by the Council of the School. On their return they communicate their impressions in reports illustrated by drawings and sketches.

Each pupil of the third year is expected to draw up a plan of working (exploitation) and a plan of metallurgy, and to terminate the third scholastic year, the engineer pupils make a second journey for instruction, of about a hundred days. On their return, they are obliged, as before, to draw up reports on the different establishments to which their attention has been drawn.

The second journey is optional for the élèves externes.

INTERNAL REGULATIONS.

The pupils are expected to remain at the School every day during the hours allotted to the courses of study and practical exercises, neither can they leave the School before the appointed time, unless authorized to do so, by the inspector of studies, or the director.

A muster is made in order to ascertain the presence of the pupils at the time appointed.

No pupil is allowed to be absent for one or more days, without the permission of the director or inspector of the School.

For constant attendance at the courses and practical exercises, marks are awarded to the pupils, which influence their definitive classification. Default of assiduity involves the loss of a certain number of these marks, and renders a pupil liable to expulsion from the School.

EXAMINATIONS.

Examinations take place at the close of the scholastic year, upon all the subjects, including the foreign languages (German and English).

All include an oral examination, in addition to a written composition.

Rising from one division to another, and the definitive classification of the pupils, depend upon the number of marks obtained in all these trials collectively, including constant attendance at lectures and practical exercises.

On leaving the School, the engineer pupils choose, in order of precedence, among the residences or positions vacant, and the élèves externes who have gone through the degrees required, receive the *brevet* spoken of at the commencement of this notice.

Prizes are awarded to the engineer pupils and the élèves externes who have distinguished themselves by their work at the School or by their travelling journals. These facts are mentioned in the brevets.

The authorities of the School cannot *guarantee* appointments for the élèves externes, but generally speaking, the influence and connections of the School are sufficient to procure positions more or less lucrative for most of the good pupils.

ASSAY OFFICE FOR MINERAL SUBSTANCES.

This office has been established near the laboratory of the School of Mines since 1845. Its special duty is to make analyses of mineral substances, which may be required by the various industrial interests, proprietors of ironworks, mines, etc. Any person wishing a substance to be assayed, must leave the specimens at the School of Mines, accompanied by the necessary details of locality and circumstances of deposit. No payment is received for assays made in the interest of mining. A report of the proceedings of the assay office is published every year in the *Journal officiel.*

NOMENCLATURE OF DOCUMENTS

PRESENTED TO THE UNIVERSAL EXHIBITION AT PHILADELPHIA.

2 volumes 8° and 4°.

Programme of admission to the preparatory and special course of the National School of Mines.

Detailed programmes of the preparatory and special courses of lectures delivered at the School of Mines.

ADDITIONAL PART.

VARIOUS INDUSTRIES ENGAGED IN THE INSTALLATION OF THE OBJECTS

EXHIBITED BY THE MINISTRY OF PUBLIC WORKS.

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Iron frame of the Exhibition pavilion of the Ministry of Public Works, executed by *A. Moisant,* builder of iron constructions, Paris, 20, Boulevard Vaugirard.

LXX

Glazed terra cotta tiles of the vestibule and façade of the Exhibition pavilion, executed by *E. Muller and Company,* at Ivry near Paris, 6, Rue Nationale.

LXXI

Mosaic paving in ceramic ware, of the vestibule of the Exhibition pavilion, executed by *Simons and Company,* at Cateau, in the department of the Nord.

LXXII

Wooden gates of the vestibule of the Exhibition pavilion, also wainscot frames of drawings, executed by *Bonhomme, uncle and nephew,* Paris, 121, Rue Notre-Dame-des-Champs.

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